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MATTI TAKALA

THE COST OF POOR QUALITY IN CARTONBOARD DELIVERIES

Master of Science thesis

Examiner: prof. Petri Suomala
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ABSTRACT

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Cost of poor quality is widely not measured in companies, even if there are many hidden failure costs affecting profitability of companies. The idea for this master thesis has risen up from case company's need for find out, how cost of poor quality is actually occurred and accumulated in deliveries. In literature quality costs are commonly categorized in prevention-, appraisal- and failure costs in so called PAF -model. Currently case company has measured only credited feedback costs, which have been allocated directly to production units. Therefore the objective was to provide more comprehensive view of quality costs in deliveries for support managerial work. How poor quality occurs, how much it costs and how it affects to customers satisfaction? With these questions it was researched, how CoPQ should be measured and what it offers for managerial work.

The research design was a single case study and it was limited to cover deliveries from one mill to one market area in one year observation period. Data for the study was collected through interviews, but even more from internal ERP -database. Based on interviews operations of delivery chain were modelled, when all volumes, sales and costs were collected from ERP- database. Poor quality activities and costs caused were categorized in internal and external failure costs, and allocated to each responsible cost object. Also lost profit was estimated as a lost opportunity. Prevention and appraisal costs were left outside of this research, since they should be more likely understood as quality investments.

As expected, poor quality cost measured with new CoPQ model were much higher than before, when also hidden costs became visible. Because costs were allocated to each responsible parts of delivery chain, mill wasn't anymore the only one who collected all costs. This is underlining the fact that comprehensively all parts are responsible for quality. CoPQ model provides support for managerial work through two models: CoPQ model itself can be used for evaluating quality and spotting targets for improvement, when cost structure model for delivery chain helps develop knowledge of delivery operations. Overall poor quality and its costs seems to be like domino blocks which are falling more blocks further this chain reaction proceed with bigger mess and consequences. Thus prevention of quality faults before they even exist should be the primary importance, and if they still exist, then it's extremely important to fix them as soon as possible.

TIIVISTELMÄ

MATTI TAKALA: HUONON LAADUN KUSTANNUKSET KARTONKITUOTTEIDEN TOIMITUKSISSA
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Avainsanat: huonon laadun kustannus, laatukustannus, laatujohtaminen, suorituksen mittaaminen, logistiikka, kartonkiliiketoiminta

Huonosta laadusta aiheutuvia kustannuksia ei yleisesti ole mitattu yrityksissä, vaikka monet piilokustannukset vaikuttavat niiden kannattavuuteen. Ajatus diplomityölle tuli kohdeyrityksen omasta halusta ja tarpeesta selvittää, miten virhekustannukset kumuloituvat toimitusketjussa ja mistä ne oikeasti kumpuavat. Kirjallisuudessa laatukustannukset on jaoteltu ennaltaehkäisy-, tarkistus- ja virhekustannuksiin ns. PAF –mallin avulla. Case yrityksessä on tähän asti seurattu vain reklamaatiohyvityksiä, jotka on kohdistettu suoraan tehtaan kustannuksiksi. Tämän työn tavoite olikin tarjota kattavampi kuva toimitusten laadusta ja kustannuksista päätöksenteon tueksi. Miten huono laatu ilmenee yrityksen toimituksissa, ja kuinka paljon siitä syntyy kustannuksia sekä miten se vaikuttaa asiakastyytyväisyyteen? Näiden myötä pyrittiin löytämään vastaus siihen, miten huonon laadun kustannuksia tulisi mitata ja mitä se voi tarjota päätöksenteolle.

Tutkimus toteutettiin case -tutkimuksena, ja rajattiin suuren datamäärän vuoksi yhden tehtaan yhdelle markkina-alueelle suuntautuneisiin toimituksiin vuoden tarkastelujaksolla. Tutkimusaineisto kerättiin haastatteluilla, mutta erityisesti yrityksen sisäisestä ERP -tietokannasta. Haastatteluiden pohjalta mallinnettiin toimitusketjun reaaliprosessi, kun taas ERP -tietokannasta pystyttiin keräämään tarvittavat myynti-, volyymi ja kustannustiedot. Virheaktiviteetit ja niiden kustannukset jaoteltiin sisäisiin ja ulkoisiin, sekä kohdistettiin jokaiselle vastuulliselle osalle toimitusketjussa. Lisäksi huonon laadun seurauksena menetetty kate arvioitiin menetettynä mahdollisuutena. Ennaltaehkäisy- ja tarkistuskustannukset jätettiin työn ulkopuolelle, sillä ne tulisi ymmärtää paremminkin laatuinvestointeina.

Odotetusti uuden mallin myötä huonon laadun kustannukset nousivat reilusti suhteessa aiempaan, kun myös piilossa olleet kustannukset tuotiin näkyviin. Koska kustannukset kohdistettiin vastuullisille osapuolille, jakaantuivat kustannukset nyt muuallekin kuin pelkästään tehtaalle. Tämä korostaa kokonaisvaltaista laatuvastuuta kaikissa toimitusketjun osissa. Työ tarjoaa päätöksen teon tueksi kaksi eri mallia CoPQ -malli, jonka avulla laatua ja erityisesti kehityskohteita voidaan arvioida paremmin, sekä toimitusketjun kustannusrakenne malli, jonka avulla voidaan luoda parempi ymmärrys toimitusketjun kustannusten muodostumisesta. Huono laatu ja siitä aiheutuvat kustannukset näyttäisi olevan kuin domino-palikat, jotka kaatavat muut palikat mennessään ja mitä myöhempänä tämä ketjureaktio pysäytetään, sitä isommat ovat seuraamukset. Tärkeintä olisi pyrkiä siis ennaltaehkäisemään laatuvirheet, ja niiden ilmetessä, korjata ne mahdollisimman nopeasti.

PREFACE

This master thesis has been performed for the master program of Industrial Engineering and Management at Tampere University of Technology. The research will create practical understanding of Cost of Poor Quality from empirical case study to scientific discussion. Original idea for this research has risen up from case company's need for measuring real costs of poor quality in their delivery chain. I want to thank my mentor Matti Ketonen who offered this opportunity for me, as well as my supervisor Professor Petri Suomala for bringing strong academic contribution to our discussions. I get always support and good advices from both of you when it was needed, but also I had enough free hands to make this project. Also I want to thank Metsä Board and all great people who I had chance to getting known and work with. It has been pleasure to work with all of you.

Like master thesis, many times our life is full of challenges, but even more, full of happy experiences and beautiful memories. However, all those everlasting memories of our life would be nothing without people around us. It's time to thank great people around me. I would like to dedicate this work for my dear family who have always support me all these years in everything I have done. Thanks for all those million miles and hours you have sacrificed for me and my hobbies. Thank you for all those wise advices you have shared with me. After all I especially want to thank my precious girlfriend, who gives me so much energy and supports me every day. Thank you for being next to me and bringing sunshine to our life even in rainy days.

For all you dear readers, if you are going to read this paper any further, please take a comfortable position, coffee next to you and enjoy. Thank you.

Espoo, 17.11.2015

Matti Takala

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LIST OF SYMBOLS AND ABBREVIATIONS

ABC	Activity-Based Costing
ABM	Activity-Based Management
BAKI	Äänekoski mill
BEAN	Port of Antwerp
CoPQ	Cost of Poor Quality
CoQ	Cost of Quality
COC	Cost of Conformance
CONC	Cost of Non-Conformance
CS	Customer
DELS	Port of Lübeck
DC	Distribution Center
ERP	Enterprise Resource Planning
FTE	Full Time Equivalent
HKO	Port of Hanko
MTO	Make-To-Order
MTS	Make-To-Stock
PAF	Prevention-appraisal-failure
PQC	Poor Quality Cost
SCM	Supply Chain Management
TQM	Total Quality Management
ZGOH	External converting in Gohrsmühle
ZWIN	External converting in Winschoten

1. INTRODUCTION

This paper will go through whole master thesis project from its backgrounds all the way to conclusions. In this first chapter background for this thesis and the case problem will be introduced. Introduction to case company and research problem as well as current issues in relevant research will provide a clear view to current circumstances. After introduction, Chapter 2 will be focusing on methodology used in this research. In that chapter all chosen research methods and guidelines will be represented. Chapter 3, 4 and 5 will focus on previous scientific research related on subject of thesis, and theoretical framework for this research will be formed. Chapter 3 will discuss closer about quality and what it means. In Chapter 4 Cost of Quality and Cost of Poor Quality will be in the spotlight, while Chapter 5 will discuss more about performance measurement. The empirical study will take place in following Chapters 6, 7 and 8, where the actual case study will be discussed more closely. Chapter 6 will describe the current situation in the case company, and so it will be a good starting point for empirical study. In chapter 7 the development process of CoPQ measure will be described and created model will be introduced. After this, in Chapter 8 results of the research will be analyzed. Finally in Chapter 9, it's time for conclusions and proposes for the future research opportunities. In the last chapter also theoretical and managerial implications will be discussed.

1.1 Background

Quality is often understood as a critical success factor for achieving competitive advantage in companies. Almost every company is somehow promoting and putting a lot of efforts to their high-quality offerings, at least when advertising their offerings to customers. However, still most companies seem to suffer a lack of knowledge, when it comes to the cost of quality, even if there's a lot of research work done and available related on cost of quality. Measuring and monitoring these costs is reported to be even more unknown within companies. This is a serious shortcoming, when we remember this old fact related to management and improvement process:

> *"If we can define it – we can measure it;*
>
> *If we can measure it – we can analyze it;*
>
> *If we can analyze it – we can control it;*
>
> *If we can control it – we can improve it."*

Thus, if companies want to improve their quality, they should be first able to control it through analysis based on measured results from well-defined object. There are many definitions and different theories for cost of quality, which makes whole concept confusing and difficult to implement for companies. There's need for clear definition for cost of quality. Maybe the biggest misunderstanding in companies is that good quality costs more than poor quality, when it's actually totally the other way around. The lack of quality is what cost for companies, and actually good quality is lowering costs in the long term. For underlining this fact, Harrington (1999) suggests to replace term "Cost of Quality" with term "Cost of Poor Quality". This cost of poor quality is also defined in many different ways. One good and clear definition is made by Juran & Godfrey (1998): "The cost of poor quality consist of all costs that would disappear if there were no deficiencies". Similarly Sörqvist (1997a) defines cost of poor quality as a company's non-value creating cost. Despite of various definitions, the authors seem to have a clear consensus that cost of poor quality is shockingly high in most companies. Harrington (1999) claims the cost of poor quality accounts for more than 40% of sales in many cases. Typically value of the cost of poor quality is estimated to be 10-40% of turnover, but it may vary a lot depending on company and used models (Krishnan 2006).

The lack of clear and unambiguous definition of Cost of Poor Quality is clearly a problem in study area of quality management. Without well-defined framework it's really difficult to make deeper research and evaluate the research findings in companies. Another shortcoming in literature is lack of practical, thorough examples of measuring quality costs. Even if authors mostly agree very high quality costs in companies, they usually compare only total costs rather than how costs have been allocated to various functions of companies or neither how these costs have been measured. More over there's no really literature of how these costs should be used in quality management, when mainly all authors are only concentrated to comparing these total quality costs between companies and industries. These issues create a research gap, which this research try to fulfill, by creating clear definition for quality costs and providing one practical way to measure cost of poor quality, as well as how this information can be used in managerial work.

1.2 The case industry and company

The empirical case study will be performed in real-world case company, Metsä Board, which is operating in paper industry, and precisely in cartonboard business. Even if these two industries are closely related together, there are many elements that make difference between them.

Paper industry has long and strong traditions in Finnish industry and whole society. It has been one of the biggest industries in Finland over hundred years and it has remained its importance for whole Finnish economy. Typical products of paper industry are different kind of papers, cartonboards, mechanical pulp and chemical pulp. Last years the demand of fine papers, like news- and printing paper, have declined which is mostly result of digitalization and the rise of developing countries. This has had a strong impact to Finnish paper industry also, because producing these products haven't been profitable enough anymore. On the other hand, increased internet shopping and growing use of tissue papers in developing countries have pushed demand of cartonboards and tissue papers increasing. For these reasons, also Finnish paper industry has shifted from manufacturing of fine papers to cartonboard and tissue paper manufacturing. (Metsäteollisuus - Toimialat [WWW] 2013)

From production point of view, paper industry is very traditional process industry, where huge volumes of products are produced in continuous manufacturing processes. Investments and fixed costs of factories are very high, which requires long-term planning and goal setting in operations. Typically products of paper industry are very functional, value per density is low and the innovation cycle is long. Usually this leads to very high standardized products. (Simchi-Levi 2010) All these special features of paper industry are affecting to fact, that the most important operational object is performance of resources. This means that the main goal for production is to maximize utilization, which is natural, because of high costs, volumes and functional products. Usually operations strategy in paper industry is concentrated to minimize all costs by high utilization and the economies of scale. (Modig & Åhlström 2013) In operations, this can be seen as a maximization of utilization: big batch sizes in manufacturing and logistics, dedicated factories and relatively high levels of inventories. Competitive advantage is created by inflexible, but very high utilized production systems, which are giving benefits through the economies of scale. (Simchi-Levi 2010; Modig & Åhlström 2013)

Even if paper industry and cartonboard industry have many similarities and sometimes they can be seen under same topic, business logic of cartonboard is still differing in many ways. Both paper industry and cartonboard industry are based on mass production and high volumes. However when products of paper industry are very functional and high standardized, it can't be said same in cartonboards. In paper business there might be only a few different product variants, which go to a few big customers, it means that whole production system can be very stabilized and based reliable forecasts. In cartonboard business there are almost as many product variations as customers, because of almost infinity amount of sizes in sheets and reels. Also cartonboard are usually coated from both or one side with different kind of coatings, which increase the amount of possible variations even more. This requires that production is able to customize products for different customer needs and can flexibly adjust to changes. Unlike paper business, in cartonboard business there's more different customers, also smaller ones. This, of course, sets its own challenges especially for delivery chain, when even smaller volumes should be delivered to customer remaining high service level, but also does it in a profitable way.

Metsä Board, the case company of this master thesis is a leading European producer of folding boxboard (FBB) and white fresh forest fibre linerboard. It's one of the five parts of bigger Metsä Group forest industry corporation. Metsä Group is a Finnish forest industry group, which has operations in 30 countries and manufacturing units in 9 of them. The parent company of Metsä Group is Metsäliitto Cooperative which is respectively owned by 122 000 Finnish forest owners. Metsä Group's total net sales in 2014 was around 5.0 billion EUR and employees in total five different business segments around 10 500. Each business segment of Metsä Group is separated in own subsidiaries, which are responsible of their own segment. Five subsidiaries, their core business segments, as well as turnover and personnels are shown below:

- **Metsä Tissue** - tissue and cooking papers (1,0 bn €, 2800 pers.)
- **Metsä Fibre** - pulp (1.3 bn €, 850 pers.)
- **Metsä Board** - cartonboard (2.0 bn €, 3100 pers.)
- **Metsä Wood** - wood products (0.9 bn €, 2300 pers.)
- **Forest Forest** - wood procurement and forest services (1.6 bn €, 900 pers.)

Organization chart of Metsä Group, and Metsä Board more specific, is illustrated in figure 1. Metsä Wood and Metsä Forest are entirely owned by Metsäliitto cooperative, the parent company of Metsä Group. Metsäliitto is also majority owner of Metsä Board, Tissue and Fibre, which are subsidiaries of cooperative. This kind of ownership and business structure distinguishes Metsä Group apart from its competitors. It also create durability and long-term secure for business. Practically through its owners Metsä Group has a significant and guaranteed supply of first-class raw materials always available. (Metsä Group [WWW] 2014)

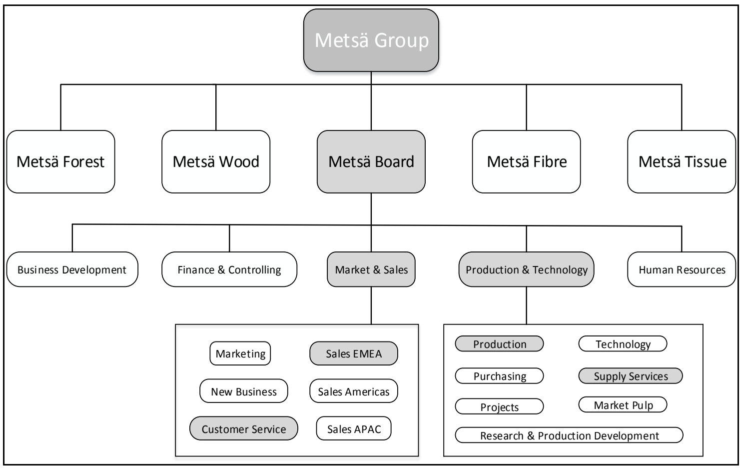

Figure 1 *Organization chart of Metsä Group and Metsä Board more specific. Grey areas are tightly related to this thesis.*

The case company Metsä Board is a subsidiary of Metsä Group, and it has focused on high-quality fresh forest fibre cartonboards. Its net sales in 2014 were approximately 2.0 bn Euros and it employed a total of 3100 people, thus it is the biggest business segment of Metsä Group. It’s also only part of Metsä Group which is listed stock markets in NASDAQ OMX Helsinki. Metsä Board is the leading producer of folding boxboard and white fresh forest linerboards in Europe. Metsä Board is also selling market pulp, which it has left over from its own needs. Products of Metsä Board are mainly used for consumer and retail packaging and graphics. Its major customers include brand owners, carton printers, corrugated packaging manufacturers and whole sellers. Metsä Board use the pure fresh fiber pulp, which is the main reason why their products are high quality, light-weight, ecological and safe. All these are features, highly appreciated by customers. (Metsä Board [WWW] 2015)

Metsä Board has production operations in total of 8 locations, of which in Finland seven and one in Sweden. Five of these locations, Äänekoski, Kemi, Kyro, Simpele and Tako in Tampere, are manufacturing cartonboard products. Currently there’s only Kyro and Husum plants, which are manufacturing also some paper products. In near future also Husum mill in Sweden will shift to manufacturing mostly, and later only cartonboards by the end of 2017. Pulp mills, which serve mainly their own production, Metsä Board has in Husum, Joutseno and Kaskinen. Metsä Board's core business is particularly cartonboard business, which is the reason why also this thesis will focus on cartonboard business and its delivery chain. Below table 1 is showing capacities in 1000 tons by every manufacturing plant. (Metsä Board [WWW] 2015)

Table 1 *Capacities of manufacturing plants.*

Capacities by mills (1000 t)					
Mill	Folding boxboard	White top kraftliner	Uncoated fine paper	Wallpaper base	Total
Tako	250	0	0	0	250
Kyro	190	0	0	105	295
Äänekoski	240	0	0	0	240
Simpele	300	0	0	0	300
Kemi	0	410	0	0	410
Husum	0	170	400	0	570
Total	980	580	400	105	2065

Table 1 shows well how Metsä Board's core competencies, folding boxboard and white top kraftliner, constitute the biggest share of total capacity. There are currently only two locations which have paper manufacturing, and its volume will still decrease when Husum mill will focus on cartonboard even stronger in the future. Table 1 show also the fact that Metsä Board's production facilities are dedicated to manufacture either FBB or white top kraftliner. (Metsä Board [WWW] 2015)

Table 2 shows more detailed way what products or items each plant is manufacturing. Table strengthens the presumption that production facilities are highly dedicated to produce a particular product family. By dedicated factories, companies usually try to achieve their economies of scale, efficiency, and keep production utilization at high level. (Metsä Board [WWW] 2015)

***Table 2** Product portfolios by manufacturing plants.*

Product portfolios by mills						
Product	**Mills**					
	Tako	**Kyro**	**Äänekoski**	**Simpele**	**Kemi**	**Husum**
Folding boxboard	Tako CX Lite Tako CX Lite OBA Tako CX Lite S Tako CX White S	Avanta Prima Carta Elega Carta Selecta	Carta Solida Carta Integra	Simcote		
White top kraftliner					Kemiart Graph+ Kemiart Lite+ Kemiart Ultra Kemiart Brite	Modo Northern Light
Uncoated fine paper						Modo Papers
Wallpaper base		Cresta				

Metsä Board's main markets are in Europe, with emphasis on Finland, Germany and the United Kingdom. The graph in figure 2 shows Metsä Board's markets by turnover in 2013 and 2014. From the graph we can clearly see the significant growth in North American market in 2014, when other markets remain stable. (Metsä Board [WWW] 2015)

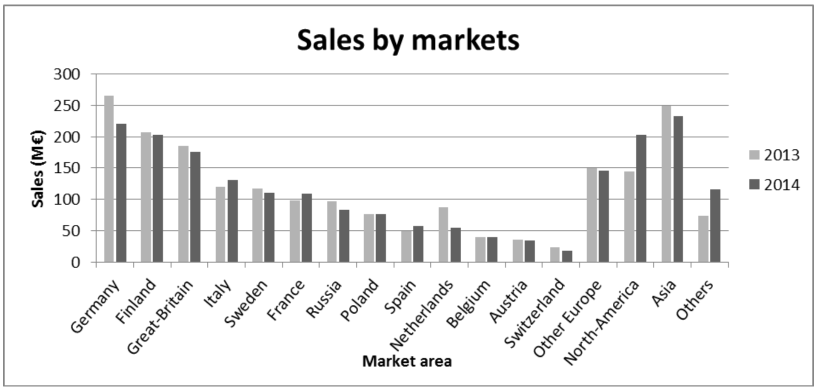

***Figure 2** The markets of Metsä Board.*

This market growth in the North American market is supporting Metsä Board's view of the huge potential in North American market. This is also contributed to the fact that Metsä Board is increasingly trying to expand and achieve a stronger market position in North America. Stronger emphasis to North American markets is clearly setting its own challenges for efficient supply chain. Larger volumes should be delivered far away from production units located in Finland and Sweden, while at the same time remaining high service levels, demanded by customers. This is an important aspect when case company is controlling its own supply chain as a whole. (Metsä Board [WWW] 2015)

In this research, we will focus on final part of Metsä Board's supply chain, which covers deliveries of cartonboards from mills to customers. Therefore, this thesis will focus only on the final product deliveries and poor quality occurring there. This delivery chain covers the supply from a total of six different mills in Finland and Sweden to customers all over the world by land and sea freight. It includes road and rail transportation, storing in ports, in rented warehouses and distribution centers, as well as maritime transportation. There might be moving and handling products from modes to another, and sometimes also containerization, particularly in deliveries to the APAC and other areas, difficult to reach. Usually products are already finished in own mills, but some deliveries can be configured for customer needs also within distribution, usually this means sheeting by external converters. At its shortest, the final product delivery occurs naturally in Finland, when the finished products are directly delivered from mill to customers by trucks. In these cases delivery times are usually hours or days. In contrast, the longest delivery times may be several weeks, when it comes to deliveries to North America and particularly in APAC. Long-distance logistics and delivery times are also factors which will certainly set their own challenges for supply chain and operations management. (Metsä Board [WWW] 2015)

For better service levels, Metsä Board offers five different supply options for their customers for filling different special needs of customers. These supply option modes are now introduced shortly:

- **Customer Dedicated Stock** – Products are manufactured for customer's special needs and specifications, and then delivered to the local warehouse of Metsä Board. From there items are delivered quickly to customer needs by call-offs.
- **Mill Direct Order** – The traditional delivery method, in which products, according to the customer's desired specifications, are delivered directly from mill to customer.
- **Common Stock** – Metsä Board has standard products in its warehouses, where customer can order products with short lead times.
- **Convert to Order** – Standardized products from common stocks are configurated for special customer needs, i.e. by sheeting, with relatively short lead times.
- **Vendor Managed Inventory** – Metsä Board handles the stock level management of customer owned stock. Customer desired products are delivered in right amount and time for customer's need. (Metsä Board [WWW] 2015)

1.3 Problem formulation and research questions

The problem of this research project has faced by case company, when they have realized the real need for better understanding about what kind of costs and effects are actually caused by failures in their delivery chain. Currently there's no measurement tool or indicator, which would measure and take account the real costs of these failures.

Metsä Board is currently measuring the cost of poor quality through credited customer feedbacks. This kind of practice is simple to use, and that's why broadly used within many companies. However, these costs are just a tip of the iceberg when calculating the cost of poor quality. The purpose of this thesis is therefore to investigate the costs of poor quality in case company, and develop new model for measuring CoPQ in more realistic way. Therefore research will give answers, how CoPQ should be measured and how this information should be used in managerial work. In addition to these customer claims inspected currently, there are several hidden costs caused by poor quality. Examples of these hidden costs in the case company would be:

- Costs caused by return defective product back to mill, and using it again as a raw material in manufacturing process by pulpering it.
- Costs or loss of sales caused by defective products sold as a second-quality at lower prices.
- Costs caused because of late or wrong delivery and corrective acts for it.
- Costs and effects caused by bad customer service and relationship (financial and non-financial effects)
- Loss of sales and future opportunity because of poor quality.

For investigating the real costs of poor quality, in this thesis we will build a model for measuring these costs and effects in case company. This model, should monitor costs of poor quality of the case company, and support management decision making process by providing more information. Thus the purpose of cost of poor quality model is to open manager's eyes for poor quality by offering broader and more realistic view for them, and help them to make better decisions. With this measure, it would be possible to get a holistic knowledge of the actual effects of poor quality and consequently try to reduce these impacts by right decisions. The purpose of the CoPQ model is therefore to provide support for management decision making process.

This master thesis will search answers for the following research questions:

1. How poor quality occurs in cartonboard deliveries of case company?

2. How much are the real costs of poor quality?

3. How poor quality affects satisfaction of customers, and what it means for business?

4. What contribution CoPQ information can offer for managerial work?

The aim of this thesis is, by answering these questions, to create a holistic view of the real costs of poor quality in deliveries of cartonboards. This research is implemented by case study in real-world company, and that's why the main and primary purpose for this research project is to solve problem in case company. Research problem in this master thesis can be illustrated by following sentence:

"The Cost of Poor Quality is widely not measured or monitored in companies, even if there's many hidden failure costs affecting profitability of companies and satisfaction of their customers"

1.4 Scope of research

As mentioned before in this thesis we will focus on real-world case company in cartonboard industry. Inspecting and modeling cost of poor quality will be focusing on that part of supply chain which starts from paper mill and end to delivering product to customer. Also return handling process for defected products will be covered, since it's causing poor quality costs. This means that research is limited to deliveries of finished products which leave from factory, and thereby we concentrate more on nonconformance quality costs. These costs are caused by fixing or forwarding any quality errors or defects occurred in supply chain after the mill. So this research will only focusing defects which already exists, and which have caused costs in various way. This thesis will not deal with prevention or appraisal costs, which are caused because avoiding defective products before they even exist or directly stopped at mill. However, by analyzing failure costs and from which sources they arise, it will be possible to allocate prevention and appraisal acts where needed.

When developing the model for costs of poor quality, probably some kind of simplifications and scoping will be needed. That means the model will be focused on one best fitting mill and its deliveries, few external converters and all possible transport modes. Thus observed delivery chain has been chosen rather because of logistic and operational reasons than quality reasons. By doing this, aim is to develop model which is fitting most of the cases, but it's still simple enough and compact to use and create. Later this model can be applied to measure another mill and its delivery chain. Overall the developed model for CoPQ should try to keep simple and light, but still effective enough and detailed for providing reliable view of these costs.

Main focus of this thesis will be research of CoPQ, how to measure it and how those costs differ from costs the case company is measuring currently. Thus, creating a model for measuring CoPQ will be in big role of this research, as well as analyzing the results after that. Hence, this new developed model for CoPQ will support decision making process by providing more comprehensive overview to quality and supply chain. Decision making based on this model, we will leave for managers. So this thesis will not give any suggestions for improvements of the supply chain or operations. However, with wider knowledge and understanding of business environment, provided in this thesis, it will be possible to find targets for improvement and then make right decisions.

2. METHODOLOGY

In this chapter the research methodology will be introduced. It starts by describing research strategy and design in general, and what should be considered in good research strategy and how it affects the success of the research. The chosen research strategy for this research will be described, as well as research process. Chapter will also describe, how literature- and empirical study was set up and how data was collected and analysed.

2.1 Research strategy and design

Research design is the general plan for answering research questions. It includes research strategy, research choices and time horizons, which all should be suitable for searching answers to research questions, which are defined for this research in previous chapter. The research “onion” introduced by Saunders et al. (2009) is describing different choices and their relationships, while designing research. This research “onion” is presented in figure 3 below. Idea of this model is to move systematically layer by layer from outer part to center, like peeling onion. (Saunders et al. 2009)

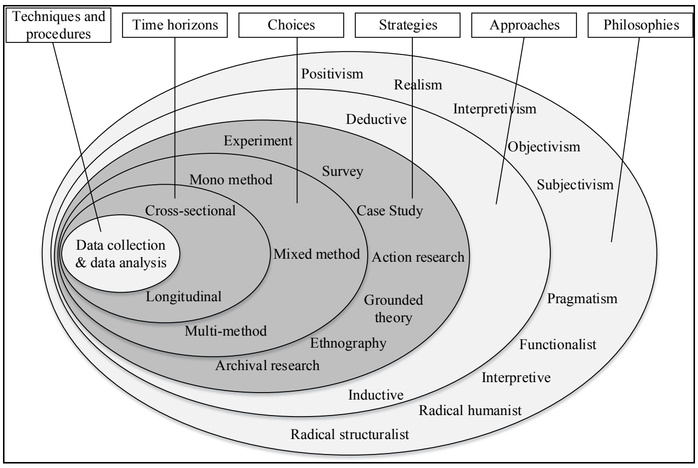

Figure 3 *Research onion. (Saunders et al. 2009, p.138)*

Before research strategy, the purpose for research should be defined. The most often research purposes are classified in three different class: Exploratory, descriptive and explanatory studies. Exploratory study is usually finding out “what’s happening”, and that’s why it focuses on new insights. Descriptive studies are concentrating to portray an accurate profile of research object. Research which try to explain causalities between variables, and why something is happening, is called as explanatory study. (Saunders et al. 2009) According to classification, the purpose of this research is combination of descriptive and explanatory study, also known as descripto-explanatory study. So, this research will describe and clarify concept of cost of poor quality both in case company, but also in generally. Addition to describing the concept, this research will also explain how much cost of poor quality is in case company, and how to measure it.

The purpose of this master thesis is to model and measure CoPQ in cartonboard deliveries. Empirical study will take a place in the case company which is a leading European folding boxboard and white fresh forest fibre linerboard producer. This case study will include solving the real-world business problem in case company. With those empirical study outcomes, this master thesis will create more practical understanding about CoPQ and bring it to the scientific discussion.

Saunders et al. (2009) are introducing seven different research strategies: experiment, survey, case study, action research, grounded theory, ethnography and archival research. This master thesis take advantage of case study research for finding answers to research questions. Case study is defined as a strategy for doing empirical investigation about research phenomenon in its real-world context (Robson 2002). Usually case study will generate well answers to questions “why?”, “what?” and “how?”, and that’s why it’s most often used in explanatory and exploratory research. Typically in case study research data is collected and analyzed by using many different sources (Yin 2003). This is improving the reliability of the research, when a same phenomenon is observed in many ways. This kind of data collection combining method for more reliable research is called as triangulation. (Saunders et al. 2009)

The time horizon for research should be decided when designing research. There are two different time horizons for research: cross-sectional and longitudinal. Cross-sectional means research which is focusing on one moment or just a short period of time, like a “snapshot”. Instead of short period, longitudinal research is observing phenomena over longer time period, usually at least one year. (Saunders et al. 2009) Because the time period for this research is limited to 6 months, cross-sectional research is the only option. Cross-sectional research horizon also fits better for this kind of research, which is measuring cost of poor quality at the moment.

This master thesis will focus on one single case in the case company. The case is about to measuring cost of poor quality in case company, and particularly in deliveries of cartonboards. This kind of “embedded single case study” is focusing on one single case inside few specific functions of case company rather than the case company as whole (Saunders et al. 2009).

2.2 Data analysis

Data collection for this research will include interviews and documented material, like historical statistics, from company’s own database. Collected and analyzed data will be in both quantitative and qualitative form. This kind of research method, where both quantitative and qualitative data is collected with multiple methods and analyzed in same research, is called as a mixed method research (Saunders et al. 2009). Interviews are mostly designed for collecting qualitative data about the processes, business model and practices used in company, but also for quantitative data from specific areas of knowledge. For example documents which the writer doesn't have access to without a contact person. Research will include also customer satisfaction survey for figure out how poor quality is affecting to customer's satisfaction. Because this kind of comprehensive survey has been just carried in case company, this research will also use results only from that survey. Documented material from company's own database will create the base for quantitative data of this research. Important source of quantitative data will be case company's own documents and files, where some information about costs related on claims, defects and delivery chain will be found. Using a mixed method data collecting in this case study research is very natural choice to create better understanding about operations and CoPQ of the case company. Figure 4 is illustrating the general structure of the research process.

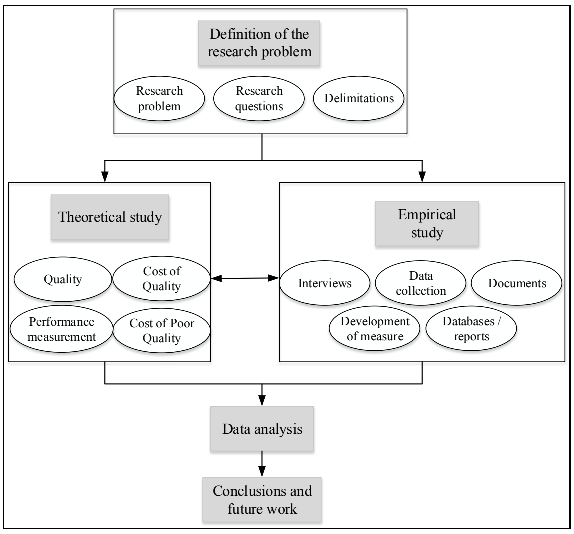

***Figure 4** Structure of research process.*

Research will begin by defining a research problem and setting up research questions and objectives. After that theoretical study will be carried out for creating strong connection and background to earlier research of this study field, as well as find frameworks for this research. This literature review will cover study fields of quality management, cost of quality, cost of poor quality and performance measurement. When theoretical background has created, empirical study will tackle to research problem including data collection through interviews, databases, reports and documents which will be used for development of measure. Data analysis will be carried out using all knowledge accumulated through theoretical and empirical study, ending up to conclusions with main outcomes and future work opportunities. Moreover the conclusion will include both managerial and theoretical implications. The structure of this paper will be following this same structure of research process.

3. WHAT IS QUALITY?

Even if quality has been researched since 1950's and it's broadly recognized as a key factor for achieving competitiveness, still understanding and measuring of quality costs is not utilized in companies. Obviously there's need for empirical study and practical understanding about Cost of Quality (CoQ) and Cost of Poor Quality (CoPQ). (Schiffauerova & Thomson 2006a) For adequate understanding of this study field and baseline for this research, literature review of previous research will be introduced.

Literature review will be carried out in next three chapters, based on following topics: Quality, CoQ & CoPQ and Performance measurement. Therefore literature review is starting from a wider study field of quality and ending up with a more specific topic, closely related to solving the case. Practical literature review process was also following this same procedure through all study fields. Research literature includes different kind of sources from more reliable sources, like books and review articles, to latest articles and seminar papers.

3.1 Definition of quality

The word "quality" is well known, and its importance has been realized widely in business life. Actually quality is so familiar for all of us that it might be even difficult to define shortly and unambiguously, what is quality. (Juran & Godfrey 1998; Krishnan 2006) If we would ask people, what quality means for them, probably we would get as many different definitions as there are answers. This is because everyone has their own expectations and needs, which define quality for them (Krishnan 2006; Oakland 2014). Usually people connect word "quality" to something superior and high valued things or excellence of products or services (Oakland 2014). However, this is not a definition of quality, but just belief. For comprehensive definition we need to think further and deeper issues related to quality. Quality might mean quite different things in different context, which appears in literature as various definitions for quality.

The story of quality research and management begins in the post-Second World War years when productivity was the major driving force in economy. Later demand stagnated and competition between organizations, and between nations, became harder than before, leading to situation which pushed companies to adopt new ways to survive. One successful way to survive was improve quality. Joseph M. Juran, Philip B. Crosby and W. Edwards Deming are the most famous pioneers in quality research. Research outcomes of these "quality gurus" are still broadly accepted and valid, even if service oriented economy has set new requirements for broader definition. (Beckford 2010)

Over the decades there have been efforts to create a short phrase, which clearly defines the meaning of quality. Juran has stated quality as “fitness for use or purpose”. This is commonly used definition, and it’s stressing that offerings should always fit for customer’s use and purpose. (Juran & Godfrey 1998) This point of view, where customer needs are in the center point of quality, seems to be common for all of these quality gurus. However all these theories differ from each other in many ways and their approaches of achieving quality are all different.

Deming, first of these quality gurus, is pointing out: “quality should be aimed at the needs of the consumer, present and future”. Deming is suggesting statistical methods for achieving better quality. Deming’s PDCA cycle is well-known approach for quality improvement, and it’s clearly pointing out that quality improvement should be continuous process. This idea of continuous improvement is supporting Deming’s idea, that companies should be able to request customer’s need presently, but also in future. (Beckford 2010, pp.67-85)

Crosby defines quality as a “conformance to requirements”, which also clearly point out, like Juran also did, the importance of customer needs. Crosby’s quality philosophy is strongly based on idea of preventive acts to create quality, rather than inspection. In this way Crosby is suggesting: “it is always cheaper to do it right first time”. (Crosby 1986) This idea can be compared to theory of Total Quality Management (TQM), which is also underlining that every individual part of organization should be responsible of quality, and focus on doing things right at once (Oakland 2014; Feigenbaum 1991). To focusing the importance of preventive acts, Crosby has said: “It’s not quality which costs, it’s non-conformance which cost”. With this sentence Crosby, unlike some other authors, want to believe that all efforts made for prevention of defects, will be free in long term, because of better quality and increased sales. Concentrating on prevent all defects, it’s possible to achieve “zero defect” level, where inspection or failure cost no longer occur. Even if Crosby (1986) is using phrase “free quality”, he is also stressing the fact that quality is not a gift, which comes free, you really need to work for it. (Crosby 1986) These kinds of phrases about “free quality” and “zero defects” are typical for Crosby, and works because they are catchy and based on sound principles (Campanella 1987). However, other authors commonly question these kinds of intensified claims. One of them is also well-known quality expert Jack Campanella, who is arguing Crosby’s “quality is free”-phrase, because its drawbacks, but also admit how catchy these kinds of phrases are. Campanella (1987) and Harrington (1999) are explaining that only in fictional company or country of Utopia, where quality is perfect, there’s no need for prevention or appraisal acts. However in real world, because of product defects and employee error, there’s need for these acts, like inspection. Efforts to reduce failure cost, or cost of non-conformance require expenditures for prevention. (Campanella 1987; Harrington 1999) And that’s why quality costs (Campanella 1987). Or similarly, that’s why poor quality costs (Harrington 1999).

Even if there are many different meanings of quality, Juran & Godfrey (1998) say there are two critical point of view about meaning of quality. These two different points of view are:

1. "Quality" means providing products which meet customer needs and satisfy them. Providing better and higher quality for customer requires investments, which costs money. Thus, higher quality usually "costs more".
2. "Quality" means freedom from deficiencies. Shortly it means that by making less defections or failures, which are making customer disappointed, will lead to quality. So, in this time quality actually "costs less".

These two meanings are often confusing, because they are both right, but at the same time they are looking at quality from two opposite perspectives. Depends which one to follow; the biggest difference is how to think about the cost of quality. Is it costing more or less to make better quality?(Juran & Godfrey 1998) Comparing these statements to different definitions of quality introduced before, we can see that Deming's theory is looking at quality from the first perspective, where Crosby is more up to the second statement. Cost of quality will be discussed in Chapter 4 Cost of Quality.

All of the philosophies are right and at the same time they all fail in some way. This is mostly because they are looking and researching quality in different circumstances. All of these philosophies are stating in one form or another "what is quality" and "how to achieve it". In another words, they are based on definition and methodology for describing the meaning of quality.

Different quality philosophies introduced before can be seen as main philosophies of quality research, in which other quality research is more or less based on. However there's huge amount of quality philosophies, and some differences can be found from all of these theories. Table 3 is shortly illustrating the most famous quality gurus and their quality philosophies.

Table 3 *The most famous philosophies of quality represented by ten quality gurus.*

Author	Philosophy
W. Edwards Deming	Quality should be aimed at the needs of the consumer, present and future. Quality should be designed into product and process.
Joseph M. Juran	Fitness for use or purpose. Quality does not happen by accident, it has to be planned.
Philip B. Crosby	Conformance to requirements, not as ”goodness” nor ”elegance”.
Armand W. Feigenbaum	Best for customer use and selling price. Quality is simply a way of managing a business organization Quality should be built in to the product rather than failure being inspected out.
Kaoru Ishikawa	Not only the quality of the product, but also of after sales service, quality of management, the company itself and the human being. ("Company-Wide Quality")
Genichi Taguchi	Non-quality is the loss imparted to society. Quality should be built in to product and process, right from the outset.
John S. Oakland	Quality is meeting the customer’s requirements.
Taiichi Ohno	The elimination of waste, and increasing the proportion of value-adding work.
Shigeo Shingo	Statistical methods detect errors too late in the manufacturing process. Instead of detecting errors it's better to engage in preventative measures.
John L. W. Beckford	Quality is contingent upon the expectations of the cutomer, not on the products or services offered. Quality must be recognized as an emergent property of the system rather than just a technical measure of output.

Introduced philosophies represent traditional quality thinking; most quality researches are based on them. However there’s some need for revised theory which fits modern business life. Beckford (2010) is partly questioning these traditional theories because they rest on well-defined, measurable characteristics of product and service. He is suggesting that in current dynamic and turbulent business environment this kind of absolute terms of quality cannot be adequately defined. Beckford (2010) explains quality through contingency theory and states quality as a contingent upon the expectations of customer, not on the products or services offered. This means quality is still meeting the customer’s requirements, but in his theory quality target, customer needs, are continually shifting. Therefore customers are continually and individually redefining quality depending on their past experiences and changing expectations. Some cases this might mean that the level of service, which met customer requirements today, is no longer enough tomorrow. Achieving quality in these circumstances needs communication, both in internal and external. External communication maintains understanding the expectations of customers, and internal is proof that organization is doing right things right. (Beckford 2010)

Comparing this revised definition to those introduced earlier, there's nothing-revolutionary change, and only the idea of continuously changing expectations and quality is a partly new idea. Almost all authors are suggesting customer‘s needs to be the corner stone when defining quality. Also many authors are recognizing quality management as a continuous improvement process, which can be seen related to responding to changing customer expectations. As a summary the connecting aspect for all these quite various definitions for quality seems to be the customer's needs, like Oakland (2014) is concluding it:

"Quality starts with understanding customer needs and ends when those needs are satisfied."

This short definition is clearly pointing out the fact that the cornerstone of quality is the customer needs. However, at the same time the sentence is underlining that also over quality can be seen as a problem. The idea of quality is to completely understand and satisfy the customer needs, but only until the point the customer will value and pay for it. Otherwise it's a waste of resources. Oakland (2014) is also reminding the importance to understand that "meeting customer requirements" as a definition of quality is not restrictive to the functional characteristics of product or service. This basically means that the customer's requirements are not always rationally decided, but many times related to other factors, like satisfaction in ownership or status symbols. That's why special requirements of customers are paramount importance in definition of quality. (Oakland 2014)

3.2 Managing quality

A traditional way to observe quality is to concentrate on manufacturing and product quality. This kind of product-oriented view to quality was natural in time when industrial companies were focusing on manufacturing physical products, and competition occurred between products. It was common that inside a company there was own quality function, which had full responsibility for product quality. Inspection was main quality control method. Later many authors started to talk about built-in quality, which moved focus more preventive acts, when products were designed in way, which eliminates quality mistakes before they exist. Still orientation stayed in product quality. Figure 5 is showing the evolution timeline of different trends of quality management. Generally quality thinking has been expanded from product-oriented quality management to cover also process and service quality, and later quality as a part of business planning. (Juran & Godfrey 1998) This same has happened when we look at quality cost systems, which is major part of quality management. Focus has drifted away from the manufacturing processes to focusing more on the total business planning systems. (Harrington 1999) Notable in this figure 5 is that today all these different parts including product-, production process-, service- and service process quality, as well as business planning are important in quality management.

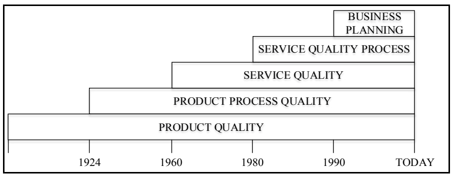

***Figure 5** The evolution of quality management focus areas. (Juran & Godfrey 1998, p.401)*

When services became more important than before and competition forced companies more comprehensive quality control, product oriented quality thinking needed to renew. Companies view to the product expanded, and started to turn from thinking of physical product to offerings, which included both physical product and service. At the same time the need for more comprehensive understanding about quality became a topic, which changed thinking from products quality to quality of processes in companies. (Juran & Godfrey 1998) Lean management and Total Quality Management (TQM) became two well-known theories related to process quality and quality as a companywide responsibility (Oakland 2014). These theories are introduced next, in so far as they related to this thesis.

The definition of lean may vary a lot depending on whom you ask and actually most of them don't even know what it exactly means. Many times lean has been understood as a tool or method, and by implementing that great lean in a company, it will fix almost everything. But obviously this is not true. (Modig & Åhlström 2013, pp.87-97) Originally lean philosophy is based on Toyota Production System (TPS), which is production philosophy invented and used in Toyota, Japanese car manufacturer. Father of TPS was Japanese quality guru, Taiichi Ohno, who originally published book of TPS in 1978. (Beckford 2010; Modig & Åhlström 2013, p.78) Ohno has said: "We just observe time from the moment when customer places an order until the moment when we receive payment from customer". With this sentence Ohno is concluding the idea, that shortening this time will increase efficiency and reducing waste. (Modig & Åhlström 2013, p.78)

Modig & Åhlström (2013) are clarifying the meaning and definition of lean, through two types of efficiency: resource- and flow efficiency. Shortly difference between these is in their different focus. Resource efficiency is focusing resources and how to maximize their efficiency, when flow efficiency is focusing flow units, like customer orders, and how to maximize their efficiency of value adding time. Concentrating to flow efficiency, will lead companies to do right things in right way, which is basically lean. (Modig & Åhlström 2013, pp.118-126)

One very important part of process quality and lean is reducing any kind of waste. This means, reducing everything which is not adding value to the product, and thus not going to provide value for the customer. Originally pointed out by Ohno in Toyota Production System, and later adopted by lean management philosophy, there are 7 types of waste:

- **Defects** – producing something which doesn't meet customer's need
- **Overproduction** – producing more than customers need
- **Transportation** – unnecessary transportation of materials
- **Waiting** – every kind of useless waiting by workers or machines
- **Inventory** – committing capital and cover mistakes of process
- **Motion** – useless motions by workers
- **Over processing** – processing products more than needed for satisfying customer (Modig & Åhlström 2013; Nicholas 2010)

By reducing this waste the company can create better flow in their operations, reduce costs caused by committed capital, create better value for customer and stop wasting money for something which customers are not paying for. All this waste reduction, is leading company toward to "doing right things in right way" and will improve their companywide quality, not only product quality, but also quality of all processes.

Quality thinking which explains quality as a companywide responsibility is commonly known as Total Quality Management (TQM). The scope of TQM covers, not only quality of product, but whole product lifecycle from concept created in R&D to after-sale operations made by customer service department. This companywide system requires effective ways to integrate and working from all humans, machines and information within all functions of organization. (Feigenbaum 1991, p.14) Oakland (2014) is writing comprehensively about TQM in his well-known book, Total Quality Management. Oakland is highlighting the reputation of company as a main goal of every company. Achieving good reputation company should implement TQM approach (Oakland 2014). Practically TQM includes many concepts and method used by leading companies, which have successfully transformed their business performance. These well-known "best practices" are collectively called "total quality" or "total quality management". (Juran & Godfrey 1998)

Through few examples Oakland (2014) is pointing out common and hidden problem in many organizations, or in our society as a whole, related to acceptance of failures. Even if usually most of the people are not accepting failures, like accidentally poisoned food in grocery or dangerous acts made by doctors, still in some cases we are accepting failures, without noticing it. Example failures in transferring information, or some non-value added processes in production system. "Why do we accept failures?" Oakland (2014) asks. In organizations these accepted, maybe originally small, failures in some stages creates problems in following stages and finally failures are cumulated to end customers, and so these originally small failures might have big consequences. For solution to this, Oakland (2014) suggests to rethink whole organization as a quality chains where different functions and stages can be think as internal suppliers and internal customers, which are linked together. These internal suppliers and customers should be responsible for quality to each other. This kind of quality chain thinking helps to recognize failures at as early stage as possible and minimize the consequences. (Stewart 2012; Hwang & Aspinwall 1996) Additionally, through this quality chain it is possible to communicate customer requirements all the way from customer interface to manufacturing shop floor and maybe until external suppliers too. Implementing quality chain thinking has been also realized to have connection to better employee motivation to do things right at first time, when they have well-defined customers inside organization. This idea of internal and external customer-supplier relationships forms the core of TQM. The importance of managing quality can be concluded, like Oakland (2014) is stating:

"Quality has to be managed – it will not just happen."

This sentence is good reminder for the fact that every company can achieve high quality with right management and right acts. But how should organizations manage quality? Like we have discussed previously, managing quality is not a separated part of business management, it should be part of everything in the organization. Krishnan (2006) is putting same in words:

"Quality should exist whatever we do. Quality must be built into the product or service that we produce, which also means that quality should be built into an organization."

TQM is one way for organizations to achieve high quality and performance excellence in their business. But what are benefits and results, company can reach with high total quality? Juran & Godfrey 1998 are listing some universally accepted goals of total quality:

- Lower costs
- Higher revenue
- Delighted customers
- Empowered employees

Usually higher quality is lowering the costs by reducing errors, rework and non-value-added work. This is also because preventive expenditures are likely to be lower than corresponding appraisal costs, which in similarly are lower than failure costs. This means, higher quality usually costs less than poor quality. In addition to lower costs, higher quality can also boost profit through improved revenue. Satisfied customers are willing to pay more and market share is increasing when new customers and markets are reached what is increasing revenue of organization. "Delighted" customers are satisfied customers who want to buy again and again. These customers are loyal for company and are remarkably more economical to retain than acquire new customers. Also empowered employees are important link to achieve high quality, but also a major goal of it.(Juran & Godfrey 1998)

4. COST OF QUALITY

Most of the companies are naturally promoting quality and customer value as a key point of their business, and a critical success factor for achieving competitive advantage. When companies are focused to offer the best possible value for their customers, they naturally aim to do it at the lowest possible cost (Oakland 2014). However, many times when it comes to quality, companies are not using all the potential of cost reduction. Actually many companies believe that cost reduction might risk their quality, what they naturally are not willing to do.(Williams et al. 1999) This is one good example how quality costs are misunderstood in organizations. That's why understanding and measuring the cost of quality should be priority issue for managers.(Schiffauerova & Thomson 2006a) By understanding the importance of CoQ, and implementing CoQ program, companies can lower their quality cost, when at the same time they are improving quality of their offerings (Gupta & Campbell 1995). Unless, companies are usually not controlling these costs by implementing CoQ, and many of them maybe don't even see the importance of reducing CoQ (Gupta & Campbell 1995). For this reason, Gupta & Campbell 1995 are setting a following question:

"Why companies aren't taking advantage of a concept that appears to offer the best of both worlds – higher quality at a lower cost?"

This question is arguing against a paradigm within companies, that higher quality is more expensive to provide, when in fact it is actually less expensive (Harrington 1999; Feigenbaum 1991). Reflecting on this issue, the need for higher understanding about CoQ in companies is obvious. Like discussed earlier about quality and its many definitions in previous chapter, also for CoQ there are many different definitions, and there's no general agreement on one single broad definition of CoQ. However, all these definitions are connected together and they have many similarities. Usually CoQ is understood as a sum of conformance and non-conformance costs (Schiffauerova & Thomson 2006a; Omar & Murgan 2014). Conformance costs are caused by all preventive acts, made for trying to prevent defects before they even exist. Non-conformance costs are all those cost caused by defective products and services.(Schiffauerova & Thomson 2006a) Similarly Gupta & Campbell (1995) have defined CoQ as any costs incurred due to bad quality, or efforts to ensure good quality.

Two American quality gurus, Juran and Feigenbaum, introduced earlier, were the first ones who identified and defined quality costs. In those early days of quality management, the cost of quality was understood and covered only as an inspection, rework, repair and warranty costs, which are nowadays categorized as an appraisal and failure costs. (Williams et al. 1999) The work of Dr. Feigenbaum has had a huge impact to research of CoQ as a whole. Already in 1943 Feigenbaum first devised a quality costing analysis, which was based on dollars. (Schiffauerova & Thomson 2006a; Harrington 1999) Later especially Harrington (1999), Juran (1998) and (Hwang & Aspinwall 1996) have all underlined the importance of using money as a measurement and communication language in CoQ. Another concept affected to CoQ research proposed by Feigenbaum in 1956. He suggested categorizing quality costs in three different categories: prevention, appraisal and failure (Feigenbaum 1991). This categorization is now widely accepted and the most CoQ models are still based on this PAF classification. (Schiffauerova & Thomson 2006a)

When it comes to levels of quality costs there are two opposite concepts, illustrated in figure 6. Even if the graphs are different, they both agree that efforts to prevent and appraise acts will reduce failure costs and defective level. So there is a trade-off between these costs. Also notable is the much steeper slope of failure costs compared to prevention and appraisal costs, what makes total costs decline when quality levels increase. The left graph illustrates traditional concept introduced by Juran and it's also called as Optimum Quality Costs. This concept believes that there is optimum level for total quality costs in point where prevention and appraisal costs equal failure costs. After this point preventive and appraisal investments are not that effective anymore, and the costs exceed the benefits, what makes total quality costs increase again. (Schneiderman 1986; Wirt 1987) However this concept is often challenged and argued that there's no economic level in quality. (Schiffauerova & Thomson 2006a; Schneiderman 1986)

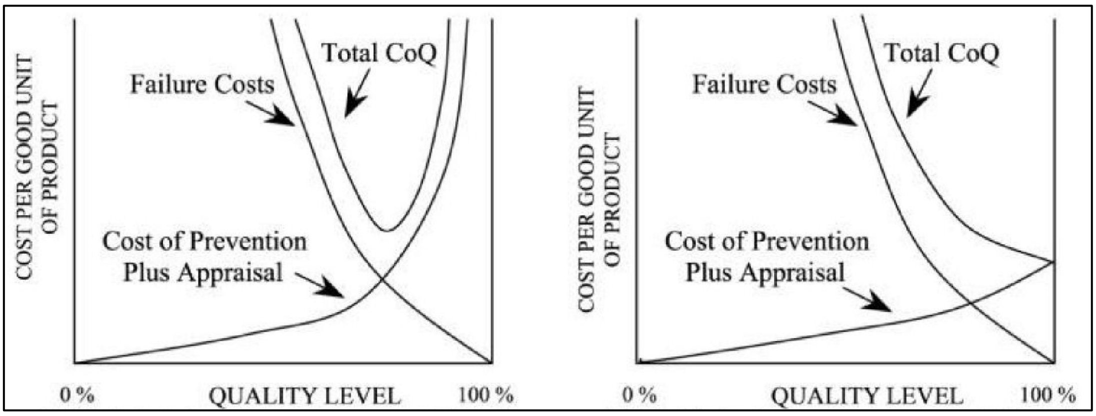

Figure 6 *The classical (on left side) and the modern (on right side) views of the optimal cost of quality. (Adopted from Schiffauerova & Thomson 2006a)*

The graph on right in figure 6 is illustrating modern concept of quality costs and it is inspired by modern ideologies like "zero defect" and "continuous improvement". This concept believes that investments on prevention can always be justified, and the optimal, economical level of quality costs equals with zero defects (Schiffauerova & Thomson 2006a; Schneiderman 1986). From the graph we can see that zero defect, or 100%

quality, level minimize the total costs of quality, and so continuous quality improvements are justified. When remembering theories by Crosby (1983), discussed earlier, we can say that zero defect level needs investments to preventive and appraisal acts, so it's not free, but at least theoretically possible and clearly worth aiming for. This modern concept is nowadays broadly agreed (Schiffauerova & Thomson 2006a; Schneiderman 1986; Juran & Godfrey 1998). Following table 4 is illustrating some of the most common definitions of CoQ stated by various authors.

Table 4 *Various definitions for Cost of Quality.*

Definitions of CoQ	
The cost of delivering customer satisfaction.	Feigenbaum (1991)
Any costs incurred due to either bad quality or efforts to ensure good quality. CoQ is a sum of four categories: Prevention, appraisal, internal failure and external failure.	Gupta & Campbell (1995)
The costs incurred in the design, implementation, operation and maintenance of a quality management system, the cost of resources committed to continuous improvement, the cost of system, product and service failure, and all other necessary costs and non-value added activities required to achieve a quality product or service.	Dale &Plunkett (1995) cited in Schiffauerova & Thomson (2006a)
Replace the term "quality cost" with "poor-quality cost", which seems more appropriate.	Harrington (1999)
The sum of price of conformance and price of non-conformance.	Crosby (1986)
The revenue lost and profit not earned.	Sandoval-Chavez & Beruvides (1998)
Prevention, appraisal and failure cost plus cost of inefficient resource utilization and quality design cost.	Modarres & Ansari (1987)
The expenditure incurred by the producer, by the user and by the community, associated with product or service.	British Standard BS4778: Part 2 cited in Krishnan (2006)
The expenditure incurred in defect prevention nad appraisal activities plus the losses due to internal and external failure.	British Standard BS4778: Part 2 cited in Krishnan (2006)
Cost in such categories as prevention cost, appraisal cost, internal failure cost and external failure cost.	British Standard BS6143: Part 1 cited in Krishnan (2006)
Cost in ensuring and assuring quality as well as loss incurred when quality is not achieved.	British Standard BS6143: Part 2 cited in Krishnan (2006)

Many of these definitions in table 4 are naturally derived from the definitions of quality. Example Crosby who defined quality as "a conformance to requirements" is defining

CoQ as “a price of conformance and price of non-conformance”. Many definitions are also affected by PAF- model, and that’s why they understand quality costs through prevention, appraisal and failure costs. Addition to PAF model, some definitions also take account the loss of opportunities, resource utilization or quality design costs. Even if these definitions more or less differ from each other, all of these definitions are recognizing both proactive and reactive costs of quality.

4.1 Quality cost models

Schiffauerova & Thomson (2006a) have successfully reviewed definitions and models of CoQ. They have categorized CoQ models in five generic models: PAF models, Crosby’s model, Opportunity or intangible cost models, Process cost models and ABC models. All these models are collected in table 5 with relative cost categories they suggest.

Table 5 *Cost of Quality models and cost categories. (Adapted from Schiffauerova & Thomson 2006a)*

CoQ model	Cost/activity categories
PAF models	Prevention + appraisal + failure
Crosby's model	Conformance + non-conformance
Opportunity or intangible cost models	Prevention + appraisal + failure + opportunity
	Conformance + non-conformance + opportunity
	Tangibles + intengibles
	PAF (failure cost includes opportunity cost)
Process cost models	Conformance + non-conformance
ABC models	Value-added + non-value-added

Even if CoQ models used in companies are always case specific and differ from each other, they are usually based on some of these generic models. All generic models are different and have their own way to categorize and understand quality costs. However, like we can see from table 5, all models have, more or less, influenced by traditional PAF model. Next, each of these quality cost models will be introduced in their own subchapters.

4.1.1 PAF models

Traditional CoQ model, PAF, can be explained shortly as a sum of three different costs: prevention, appraisal and failure costs. PAF model is the most common way to explain and understand CoQ. (Williams et al. 1999; Schiffauerova & Thomson 2006a; Gupta & Campbell 1995; Sandoval-Chavez & Beruvides 1998; Tsai 1998) This model, originally devised by Dr. Feigenbaum in 1956, has later been refined and nowadays failure costs are usually divided in internal and external failure costs. Today this refined and expanded model provides an excellent tool for management, used to measure the effectiveness of the quality system and direct quality improvements (Harrington 1999). This PAF-model, with four cost categories: Prevention, appraisal, internal- and external failure costs, have been universally accepted and successfully used in both research and business environment. (Schiffauerova & Thomson 2006a; Krishnan 2006) Next, each cost categories of PAF model will be explained.

Prevention Cost – Those costs, company expends for preventing quality problems before they even exist. (Schiffauerova & Thomson 2006a; Gupta & Campbell 1995; Oakland 2014; Krishnan 2006; Crosby 1986) Prevention costs avoid defects and non-conformities occurring and stop unsatisfactory products coming about in the first place, and so it will also minimize appraisal and failure costs (Feigenbaum 1991; Krishnan 2006). These prevention costs are planned, proactive costs, which include example the following activities:

- Quality Planning.
- Design and development of quality measurement and test equipment.
- Quality review and verification of design.
- Calibration and maintenance of quality measurement and test equipment.
- Calibration and maintenance of production equipment used to evaluate quality.
- Supplier assurance.
- Quality training.
- Quality auditing.
- Acquisition analysis and reporting of quality. (BS6143: Part 2 1990; Crosby 1983; Krishnan 2006; Oakland 2014; Feigenbaum 1991)

This cost category has been agreed by experts to be the most cost-efficient category, because these investments can totally prevent defections and all the costs caused by defections (Gupta & Campbell 1995). Resources used for prevention give rise to the "cost of doing it right at first time" (Oakland 2014).

Appraisal Cost – Costs incurred to assure the degree of conformance to quality requirements. (BS6143: Part 2 1990; Crosby 1983; Gupta & Campbell 1995; Krishnan 2006; Oakland 2014) Therefore, appraisal costs are used maintain company quality levels through formal evaluations of product quality (Feigenbaum 1991; Gupta & Campbell 1995). Usually appraisal costs are understood as costs of following activities:

- Pre-production verification.
- Receiving inspection.
- Laboratory acceptance testing.
- Inspection and testing.
- Inspection and test equipment.
- Materials consumed during inspection.
- Field performance testing.

- Approvals and endorsements.
- Stock evaluation.
- Record storage. (BS6143: Part 2 1990; Crosby 1983; Krishnan 2006; Oakland 2014; Feigenbaum 1991)

Appraisal costs are not including rework or reinspection costs caused by failures, because those costs are included in failure costs explained in following paragraphs. (BS6143: Part 2 1990)

Failure Cost - Costs caused by poor quality, failures or defective products and services. Usually failure costs are subdivided to external and internal failure costs (BS6143: Part 2 1990; Crosby 1983; Gupta & Campbell 1995; Krishnan 2006; Oakland 2014).

Internal Failure Cost - Costs discovered before the transfer of ownership to customer, so the failure has detected by own staff after inspection in manufacturing, but before customer (BS6143: Part 2 1990; Feigenbaum 1991; Gupta & Campbell 1995; Krishnan 2006; Oakland 2014). Addition to manufacturing and logistics cost of defective product, internal failure costs include also costs caused by replacing product and wasted extra work for handling failure. Internal failure costs can be identified as costs of following activities:

- Scrap.
- Replacement, rework and repair.
- Troubleshooting or defect/failure analysis.
- Reinspection and retesting.
- Faults of subcontractor.
- Modification permits and concessions.
- Downgrading.
- Downtime.
- Customer service. (BS6143: Part 2 1990; Krishnan 2006; Oakland 2014; Feigenbaum 1991)

Because internal failure costs include a lot of various committed costs, they are much more expensive and harmful for company than prevention or appraisal (Gupta & Campbell 1995). However, usually these costs are still much lower than external failure costs, which are introduced next.

External Failure Cost - Costs discovered after transfer of ownership to customer, so the failure has detected by customer (BS6143: Part 2 1990; Feigenbaum 1991; Gupta & Campbell 1995; Krishnan 2006; Oakland 2014). It's clear that these kinds of failures are the most violent and the most expensive for company. This includes all costs committed because of manufacturing, delivering and replacing defective product to customer, troubleshooting and after all the loss of reputation.(BS6143: Part 2 1990) External failure costs can be break down as costs of following activities:

- Complaints.
- Warranty claims.
- Products rejected and returned.
- Concessions.
- Loss of sales.
- Recall costs.
- Product liability. (BS6143: Part 2 1990; Krishnan 2006; Oakland 2014; Feigenbaum 1991)

As a conclusion for these four quality cost categories Gupta & Campbell (1995) are stating this basic principle:

“The earlier the problem is detected, the less the effort required to resolve it”

By this sentence Gupta & Campbell (1995) try to clarify the importance of allocating CoQ expenses. It is broadly agreed that investments to proactive acts are much more cost-efficient than reactive ones. Even old wisdom is telling same fact: “an ounce of prevention is worth a pound of cure.”(Gupta & Campbell 1995) Figure 7 is illustrating the relation between prevention, appraisal and failure costs, and how these quality costs together form total quality related costs (BS6143: Part 2 1990).

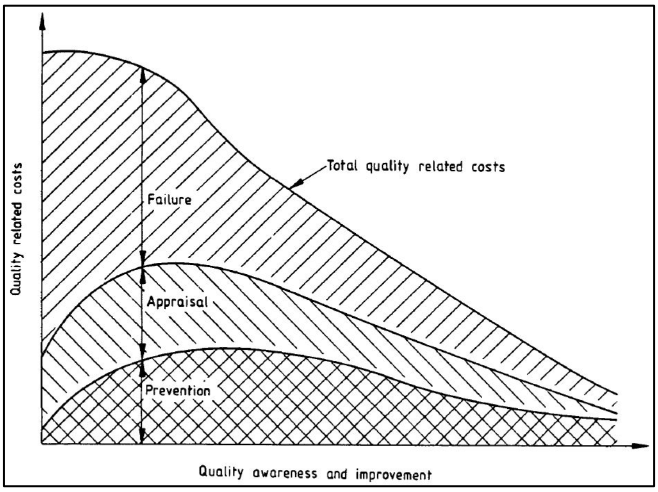

***Figure** 7 Relation of quality improvement to quality related costs (prevention, appraisal and failure costs). (Adopted from British Standard BS 6143: Part 2, 1990, p.1)*

From the graph above we can clearly see, how failure costs generate the largest portion of total quality costs in the beginning, but while efforts to prevention and appraisal acts increase, failure costs begin to radically decline (BS6143: Part 2 1990). This basic principle is easy to understand and accept when we think about how committed costs are cumulating in whole order-delivery process. For example if a defective product is detected by inspection in production unit, it will cost as much as manufacturing costs and costs spend in preventive and appraisal acts. However if this defective product already passed inspection and not detected until distribution center far away, committed costs will now include also some logistics costs etc. The worst situation is, if defective product is not detected before customer. In that case, all committed costs are maximized, and addition to these, now also customer realizes poor quality which causes harm and costs for them. Because of this external failure, the company can lose its reputation and customer at once. In addition to all these cases, defective product is also causing extra work because of handling and solving the problem situation. As a result, originally maybe little mistake in some point of order-delivery chain was accumulated to huge failure, when it arrived all the way to customer. However if the company has made some preventive investments, like education or error-proof manufacturing system, they could have maybe avoid whole error, and moreover huge failure costs caused. Preventive and appraisal acts are more cost-efficient than curing made failures. This is why companies should invest largest portion of quality cost to prevention category and second largest portion to appraisal, and try to eliminate failure costs (Gupta & Campbell 1995; Schiffauerova & Thomson 2006a).

4.1.2 Process cost models

Previously introduced models have focused mainly on product and service which provide value to the customer. However, in modern TQM culture, discussed earlier, all business activities and improvements are related to processes, not only outputs. Therefore also CoQ model should be reflecting the performance of processes rather than arbitrarily defined CoQ (BS 6143: Part 1 1992; Schiffauerova & Thomson 2006a; Oakland 2014). Also traditional categorization in PAF models has been criticized to be difficult and unnecessary (Oakland 2014; Krishnan 2006; BS 6143: Part 1 1992). Process cost model, developed by Ross (1977, cited in Schiffauerova & Thomson 2006a) another way to define CoQ. It's focusing on process rather than product, and it's measuring total conformance and non-conformance costs for particular process. The "process" in this model can be defined in any level within a company, from a special work stage to wider business processes. Costs can be measured in every step of the process, and then analyzed if further efforts on failure prevention activities or process redesign are needed. (BS 6143: Part 1 1992; Schiffauerova & Thomson 2006a; Schiffauerova & Thomson 2006b)

According to British Standard BS 6143: Part 1 (1992), process cost model is constructed by identifying and monitoring process and its key activities. Also the owner of the process should be identified and involved to improve the process. Figure 8 shows the basic view of process model. Usually from any process, it's possible to identify inputs and outputs, as well as controls and resources used.

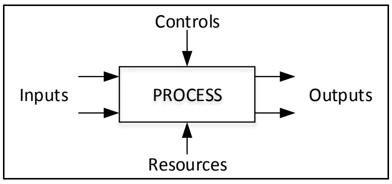

Figure 8 *The basic process model. (British Standard BS 6143: Part 1, 1992, p.2)*

When the process and its key activities are identified, the cost of conformance and cost of non-conformance elements for each activity should be identified. After a process model has been constructed, all the costs will be calculated or estimated, if the required accounting data not available, at each stage. Finally, as a result, a process cost summary report can be constructed, and quality related costs and allocations for each stage can be analyzed. (BS 6143: Part 1 1992; Oakland 2014)

4.1.3 ABC models

The common shortcoming of all introduced CoQ models is that they are poorly fitted together with existing accounting systems. This is because traditional accounting systems are not providing quality related data, and even if CoQ models are activity oriented, cost accounting is still establishing cost accounts by expenses. This leads CoQ models making estimations and collecting data with other methods. Another problem with traditional accounting systems is that they are not allocating overhead costs to CoQ elements or tracing quality costs to their sources. (Schiffauerova & Thomson 2006a; Tsai 1998) Practically this might mean that, for example quality cost caused by a mistake in sales operations can be assigned to manufacturing function, because of the traditional volume-based cost assignment. This is hindering managers to see the real sources of quality costs, and the targets of quality improvement (Tsai 1998).

Solving these drawbacks of traditional CoQ models, the framework of “Activity-Based Costing” (ABC) has been suggested to fit well for CoQ purpose. ABC is not originally CoQ model, but it can be used with those traditional models, introduced earlier. This well-known ABC model is developed by two accounting gurus, Cooper & Kaplan in 1988. The idea of ABC model is to allocate overhead costs for various costs objects by tracing resource cost to their respective activities and the cost of activities to cost objects. The cost assignment has carried out by using suitable drivers based on the performance of activities. (Cooper & Kaplan 1988) The goal of ABC system used for measuring CoQ is that no defects are produced by eliminating non-value added activities and improve processes, activities and quality. (Schiffauerova & Thomson 2006a) Figure 9 illustrates the basic procedure of ABC.

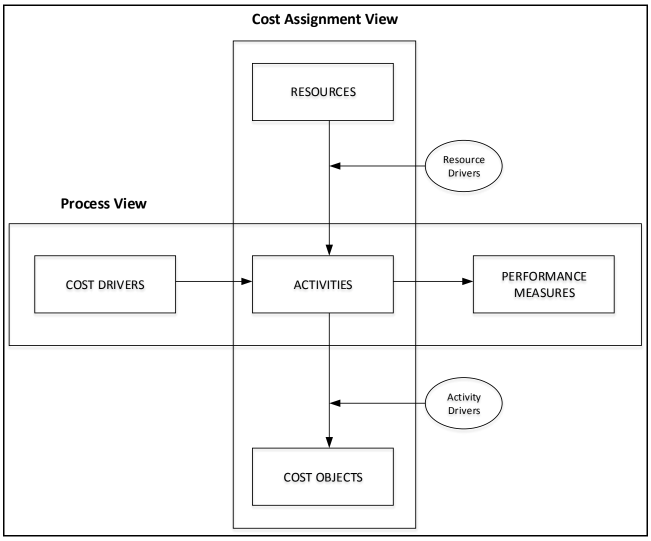

Figure 9 *Two-dimensional model of ABC. (Tsai 1998)*

Two dimensions of the ABC model are cost assignment view and process view, which are composed together. In cost assignment view, cost objects like processes, creates the need for activities, which are using different kinds of resources. Assigning costs of used resources to activities and finally to cost objects is two-staged procedure. First, resource costs are assigned to various activities by using resource drivers, which approximate the consumption of resources by activities. One type of resource, which is assigned to specific activity, is called as a cost element and all costs elements related to same activity, forms one activity cost pool. Thus one activity cost pool is representing the total assigned cost for specific activity. Together these activity pools form activity center, which can be clustered by function or process. Similarly in second stage, the costs earlier assigned to activity pools are now distributed to specific cost objects, by using activity drivers. These drivers measure the consumption of activities by cost objects. Thus, every cost object will collect as much costs as they have generated. (Tsai 1998)

Another dimension of the ABC model, the process view, includes three building blocks: cost drivers, activities and performance measures. Cost drivers are identifying the cause of activity cost, the workload and effort needed to perform specific activity. Respectively performance measures are indicating how well activities are performed, and how the activity is meeting the needs of internal or external customer. Activities in this model have been categorized to value-added and non-value-added activities. Value-added activities are all activities which are contributing value to customer or satisfy company's need. All the rest activities are counted as non-value-added activities. (Tsai 1998)

This two-dimensional ABC model has been successfully applied to CoQ measurement by Tsai (1998) in his integrated CoQ-ABC framework. In this integrated framework cost assignment view is activity-oriented, like PAF model in CoQ, and process view is naturally process oriented, like process cost approach of CoQ (Tsai 1998). So, both of these CoQ models, discussed earlier, are now integrated and incorporated together with

ABC model. This integrated ABC model can provide more accurate costs of activities and processes than traditional models (Tsai 1998). Integrated CoQ-ABC framework, and how it combines activity-based management (ABM) and TQM together, is illustrated in appendix 1. We can see how the TQM framework, discussed earlier, has been regenerated with ABC model to provide more accurate and comprehensive framework for measuring CoQ.

Integrated CoQ-ABC framework is started by defining the critical business processes and flowcharting selected processes. After this the framework follows ABC procedure, by using CoQ-related activities (prevention, appraisal, internal failure and external failure), which were categorized with PAF model. Assigning resource costs to these activities, the cost of quality can be measured by activities. These costs of quality related activities can be then distributed to responsible cost objects, like products, functions or processes. For the process cost approach, various processes can be flowcharted and COC and CONC-related activities used in ABC model. Tracing the resource costs is the same as with PAF approach before, but now the results from cost assignment view would be the cost of flowcharted activities. (Tsai 1998)

4.1.4 Other CoQ models

Crosby's model is created and named by P.B. Crosby in 1979, and it sees quality as "conformance to requirements. That's why Crosby's model defines CoQ through conformance and non-conformance costs, introduced earlier. (Schiffauerova & Thomson 2006a; Schiffauerova & Thomson 2006b) Even if this model is totally its own model, the idea is basically same as it is in PAF- model, but Crosby is using different terminology (Goulden & Rawlins 1995). Through different terminology Crosby's model is focusing and highlighting more customer conformance. This same categorization to conformance and non-conformance cost have been used more successfully in process cost models.

One thing which earlier introduced models haven't considered is opportunity and intangible costs. These costs can be estimated as a loss of profit, sales or any opportunity, which have been lost because of poor quality (Schiffauerova & Thomson 2006a). Sandoval-Chaves & Beruvides (1998) have divided opportunity losses into three components: underutilization of installed capacity, inadequate material handling and poor delivery of service. Also lost profit is usually included in opportunity costs. Many times opportunity and intangible costs have been used for expanding traditional PAF models. (Modarress & Ansari 1987; Sandoval-Chavez & Beruvides 1998)

4.2 The importance of CoQ

Why these quality costs are important, and why companies should measure, follow-up and especially try to reduce them? Williams et al. (1999) with many other authors are stating that quality costs are very large and represent a considerable proportion of a company's total costs and sales. Most of the companies don't even realize how large these costs can be. Also Crosby (1983) claims quality cost being huge, around 25-30% of sales in manufacturing companies and even 40-45% of operating costs in service companies. Maybe the wildest numbers are represented by Harrington (1999), who claims these cost can be even more than 40 percent of sales. However based on various studies made by Dale & Plunkett (1999) they have realized that quality-related costs commonly range between 5 and 25 percent of annual sales (Williams et al. 1999). Also Giakatis et al. (2001) estimate that generally in literature quality costs are reported to be between 5 and 30% of sales. Because of these huge numbers, CoQ are called as a "hidden factory" or "the gold mine" (Krishnan 2006). Of course these costs always depend on type of company and industry as well as their business situations and way to measure these costs. However, reducing these total quality costs, profit of organization is directly increasing, and through better quality also returns are likely to increase at the same time (Neilimo & Uusi-Rauva 2010). All these aspects give us the understanding about significance of quality costs. (Williams et al. 1999; Giakatis et al. 2001) However understanding the significance of these costs is just a beginning. Cost of quality should be after all used for measuring performance and improving quality continuously rather than just reporting and cutting quality costs. Measuring cost of quality should give information about targets of improvements and support management decision making process to make progress.(Juran & Godfrey 1998) Williams et al. (1999) are listing some reasons, why knowledge of quality costs is important for managers and what can be the benefits of it:

- By providing hard facts and figures, it helps managers to justify the investment in process of continuous improvement.
- Assists them in monitoring the effectiveness of the efforts made and in assessing the impact of various improvement initiatives and activities.
- Helps to reduce the number of errors and mistakes along with the associated costs.
- It will free-up resources, like employees time, and help to use them in more effective way

Similarly, Tsai (1998) has listed some of the important uses of CoQ information for management:

- To identify the magnitude of the quality improvement opportunities.
- To identify where the quality improvement opportunities exist.
- To plan the quality improvement programs.
- To control quality costs.

These lists could be extended with many other authors, like Krishnan (2006), who have listed similar benefits or uses of CoQ measurements. These lists and estimations of general amount of CoQ give already some kind of view about the importance and significance of CoQ, and especially importance of continuous quality improvements.

Like all managerial frameworks and theories, none of them are making miracles alone. Measuring and reporting quality costs should never do just without purpose or improvement process. Only reporting quality costs don't improve quality or reduce costs. (Tsiakals 1983, cited in Williams et al. 1999) Sometimes organizations might believe that some new frameworks or ways to do things better will fix all their problems. It's exactly same with quality costs, organizations should not expect too much from CoQ. Also some managers mistakenly suspect that measurement of quality cost can actually deflect attention from their reduction and also it could be harmful for continuous improvement. (Morse 1983, cited in Williams et al. 1999) All these kinds of harmful beliefs might lead to the whole improvement process to fail. In this point it's maybe good to remind all managers, who read this paper, to keep these warnings in mind when implementing and using quality costing system. Gupta & Campbell (1995) are concluding this in one sentence:

"COQ has nothing to offer those searching for a quick fix or an easy answer. But for corporations willing to go that extra mile, COQ sets the stage for continuous improvement and cost-effectiveness."

4.3 Cost of Poor Quality

Previously the theory of quality and the Cost of Quality have been introduced and discussed. In this section the focus is sharpening toward Cost of Poor Quality, which is the core theory of this thesis. Study areas of CoQ and CoPQ are not clearly defined or separated each other in literature, and definitions of main terms are varying from author and situation to another. For this reason, CoPQ will be defined in a way it has been understood and used in this thesis. This definition of CoPQ will create the core framework for empirical study of measurement of CoPQ.

According to Juran & Godfrey (1998), CoPQ can be defined shortly as:

"All costs that would disappear if there were no deficiencies – no errors, no rework, no field failures, and so on. This cost of poor quality is shockingly high."

Even if this definition sounds clear to understand, there seems to be many different definitions for CoPQ in literature. Krishnan (2006) has also realized that there's often some misunderstanding and confusion between terms Cost of Quality (CoQ), Cost of Poor Quality (CoPQ) and Poor Quality Cost (PQC). Sometimes difference between these definitions is nothing else than way to name it. Example Harrington (1999) wants to use PQC for same purpose as CoQ is usually used. This is because "quality cost" leaves a negative impression and he wants to highlight the fact that it's poor quality which costs, not good quality. (Harrington 1999) On the other hand Juran & Godfrey (1998) are using term CoQ as equal with CoPQ. To make things even more confusing some authors are using totally different terms, like Giakatis (2001), who is talking about quality losses or hidden quality losses. Similarly, Krishnan (2006) is discussing about "visible" and "less visible" hidden costs of quality. These are just a few examples how disorderly these terms have been defined, and how confusing it is. Because the lack of clear and established framework for CoPQ, it's necessary to take a look at few CoPQ concept and create a general view based on these theories. We will go through theories by Juran & Godfrey (1998), Harrington (1999), Sörqvist (1997a), Giakatis et al. (2001) and Thomasson & Wallin (2013).

Juran & Godfrey (1998) are defining CoPQ as a sum of three elements: cost of nonconformities, cost of inefficient processes and cost of lost opportunities for sales revenue. Simple structure of CoPQ by Juran & Godfrey (1998) is shown in figure 10. This classification is clearly leaving prevention costs outside of the CoPQ. Cost of nonconformities and cost of inefficient processes can be understood as internal and external failure cost, what we have discussed many times earlier. Juran & Godfrey (1998) are blaming traditional concepts too limited, when they usually ignore lost sales and inefficient processes due to poor quality. Strictly CoPQ can be defined through these three elements (figure 10), and shortly as a sum of internal and external failure costs, if failures in appraisal acts are included to internal failures. (Juran & Godfrey 1998)

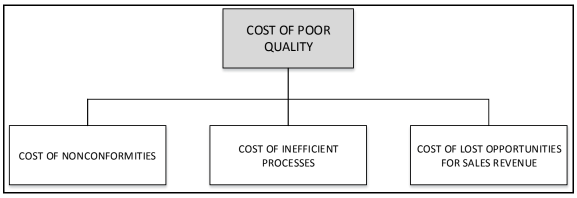

Figure 10 *Structure of CoPQ by Juran & Godfrey (1998).*

Unlike Juran & Godfrey (1998) left prevention and appraisal costs outside of CoPQ, Harrington (1999) is suggesting to include prevention and appraisal in concept. He is using term Poor Quality Cost (PQC) which he is defining as "all the costs incurred to help the employee do the job right every time and the cost of determining if the output is acceptable, plus any cost incurred by the organization and the customer because the output didn't meet customer expectations". This definition is pretty wide and can be also understood as CoQ definition. In this concept Harrington (1999) is dividing costs to direct and indirect costs, depends how these costs can be measured. Similarly Krishnan (2006) is using terms visible and hidden failure costs for same purpose. CoPQ classification by Harrington (1999) is illustrated in figure 11.

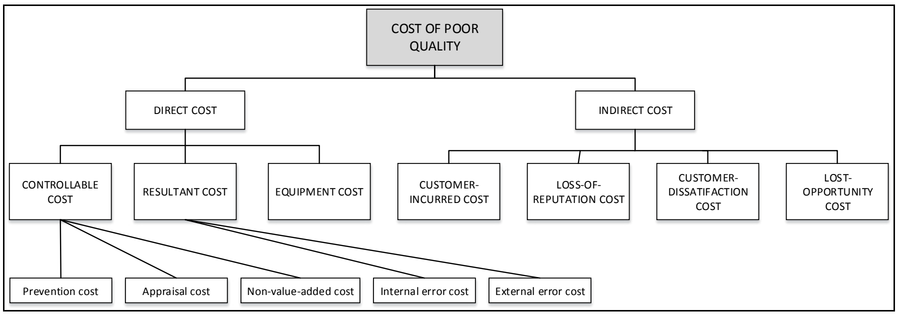

Figure 11 *Elements of CoPQ by Harrington (1999).*

Direct costs include controllable costs (prevention, appraisal and non-value added cost), resultant costs (internal and external errors) and equipment costs. These costs can be measured directly, and basically covers similar costs as CoQ models introduced earlier. Indirect costs are more difficult to measure since they include costs related to customer, loss-of-reputation, customer dissatisfaction and lost opportunities. (Harrington 1999) In these costs we can see similarities with concept of Juran & Godfrey (1998) which also included opportunity costs as an important part of their concept.

One another famous CoPQ author is Lars Sörqvist, who has made a wide-range research project with Lennart Sandholm in Swedish companies related on CoPQ. Their aim has been to develop an effective method of measuring CoPQ. Sörqvist (1997a) is defining CoPQ as a "costs which would be eliminated if a company's products and the processes in its business were perfect". He also stresses that, even if prevention costs have been included earlier, they should rather be classed as an investment to quality, not CoPQ. He also states that available information of prevention costs is never sufficient enough, because it highly depends what costs are counted in.(Sörqvist 1997a) In figure 12 the concept of CoPQ is illustrated. Basic concept of CoPQ is built up with three elements: appraisal costs, internal failure costs and external failure costs. Comparing this to CoQ models introduced earlier, only difference seems to be excluding prevention costs. Also Sörqvist (1997a) is not recognizing opportunity costs at all, even if many other authors do.

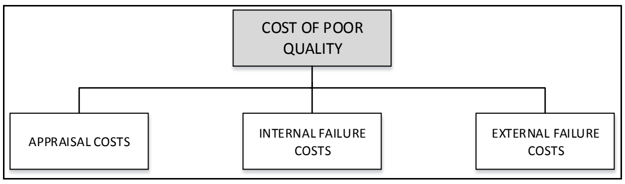

Figure 12 *Elements of CoPQ by Sörqvist (1997a).*

Another concept which is not including opportunity costs is introduced by Giakatis et al. (2001) illustrated in figure 13. Instead of this missing opportunity costs, this concept is introducing new idea of quality losses. The distinction between quality costs and quality losses is that quality costs are adding value while quality losses are not adding value and sometimes even reducing it. They are defining these terms as follows:

- **Quality costs** – the cost for the company of every effort that sustains or improves the certainty that the product meet or will meet the specified requirements.
- **Quality loss** – the money spent because a quality cost failed to sustain or improve certainty and hence non-conformances occur. There is no present or future benefit expected.

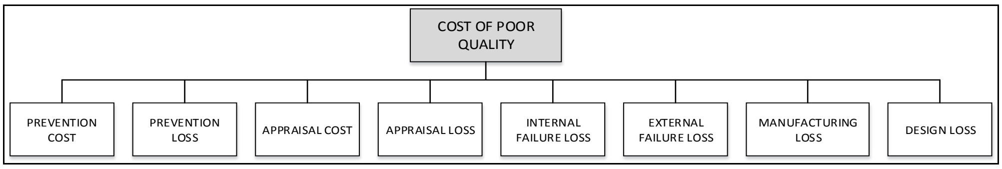

Figure 13 *Elements of CoPQ by Giakatis et al. (2001).*

Based on this distinction CoPQ model is expanded with quality losses. Failure costs are now categorized as failure losses since they are not adding value or there are no expected benefits. Also prevention and appraisal costs should be divided to prevention loss and appraisal loss. This is because they are not always successful and that's why they cause failures. In addition Giakatis et al. (2001) are including two more loss elements, manufacturing loss and design loss, to CoPQ model. These important but hidden costs are caused because of inefficient use of resources and failures in process design. (Giakatis et al. 2001)

Concepts introduced so far have been review and summarized by Thomasson & Wallin (2013) in their master thesis. From this framework, illustrated in figure 14, we can clearly see combination of concepts introduced before. Thomasson & Wallin (2013) have followed Giakatis et al. (2001) when including prevention and appraisal losses. However they are not including prevention or appraisal costs because, like Sörqvist (1997a) claimed, these costs can be understood as an investment for quality. Failure costs are divided to internal and external failures, as usual, but apart from others, Thomasson & Wallin (2013) are also including waste costs under failure costs. This is related to their case which had strong connection to lean manufacturing, and theory of wastes.

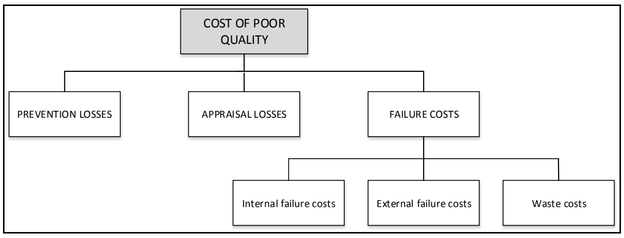

Figure 14 *CoPQ elements by Thomasson & Wallin (2013).*

We have now introduced some of CoPQ approaches, and realized how they differ from each other. Every one of them has created for specific purpose and has their strengths and weaknesses. For summarizing all these concepts figure 15 is illustrating the summarized framework of CoPQ, used in this research.

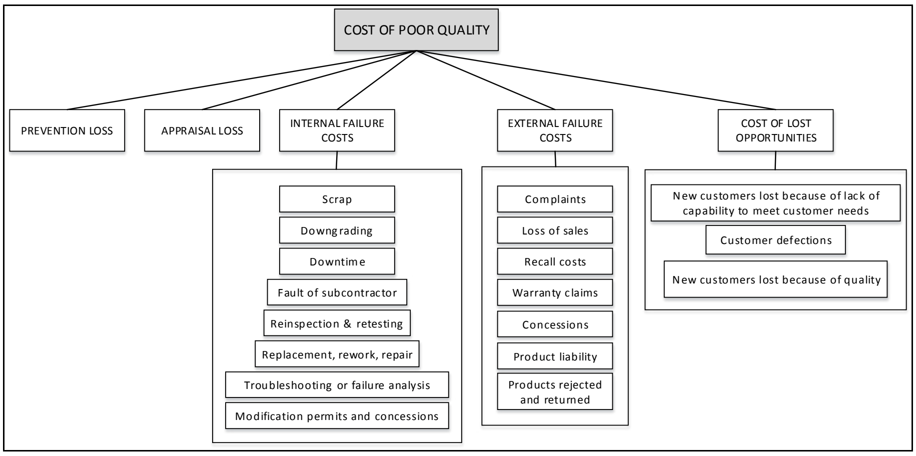

Figure 15 *Summarized CoPQ framework.*

In this framework, prevention and appraisal costs are not included, because they can be understood as investments for better quality (Sörqvist 1997a). Instead of that, prevention and appraisal losses should be included to CoPQ, because these costs arise from failures in prevention and appraisal acts (Giakatis et al. 2001). Failure costs are divided to internal and external failure costs, like all introduced authors did before. Cost of lost opportunities have been included also because it's clearly result of poor quality and that's why should also take into account (Juran & Godfrey 1998; Harrington 1999). Internal and external failure costs, as well as cost of lost opportunities have been broken down further according to classifications by British Standard BS 6143: Part 2 (1990) and Juran & Godfrey (1998).

For make it clear, in this research, all these terms CoQ, CoPQ and PQC, mentioned before, will be understood and used as their own different terms. These quality-related terms are defined as:

- **Cost of Quality** – A sum of conformance and non-conformance costs, where cost of conformance is the cost caused by prevention of poor quality and non-conformance is the cost caused by defective product or service. (Schiffauerova & Thomson 2006a)

- **Cost of Poor Quality** – All costs that would disappear if there were no deficiencies – no errors, no rework, no field failures, and so on (Juran & Godfrey 1998). It covers all costs caused when product or service fails to conform to customer requirements. It includes internal- and external failure costs, opportunity costs, as well as prevention- and appraisal losses. It doesn't include prevention or appraisal costs, because these are understood as quality costs.

- **Poor Quality Cost** – All the cost incurred to help employees to do their job right every time and the cost of determining if the output is acceptable, plus all costs caused if output didn’t satisfied customer needs (Harrington 1999).

5. PERFORMANCE MEASUREMENT

Every decision managers make should be based on reliable and sufficient information (Juran & Godfrey 1998). Management accounting information enhances decision making, guides strategy development and evaluates existing strategies, and helps to evaluate current performance of organization, as well as focus efforts related to improving performance (Kaplan & Atkinson 2014). The importance of performance measurement has been expressed many times, like Krishnan (2006):

"If there is need to control anything, the first thing to do is measure."

This sentence is stressing the fact that all decisions and improvement processes should start with measuring and collecting information needed. Quality is not an exception, and that's why this chapter is related to performance measurement. The purpose for this chapter is to give an overview of performance measurement and what is needed for good measurement. After the general overview, measurement of CoPQ and its relation to decision making process is discussed.

5.1 Characteristics of good performance measurement

Performance can be defined as an ability of measured object to reach the goals set in advance (Neilimo & Uusi-Rauva 2010). Respectively a performance measurement is defined as a metric used to quantify the efficiency and/or effectiveness of an action or an end-result (Neely et al. 2005; Suomala et al. 2007). Measurements can be financial or non-financial based and it should be always connected to real-world operations and the decision making process. It has said: "You get what you measure", which underlines the important role of measurement for management, and the decisions made. The information, which measurement is producing, is essential for successful management, and that's why also the quality of information should be guaranteed. (Neilimo & Uusi-Rauva 2010)

Neilimo & Uusi-Rauva (2010) have listed few criteria which determine the feasibility and effectiveness of information to the decision making process:

- Relevance – Meaningful and important for decisions made.
- Topicality – Should be recently collected.
- Reliability – Trustfully representing its object.
- Accurate – Should be enough accurate for better view of phenomena.
- Practical – Give enough practical view of real-world phenomena.

- Illustrative – Illustrative form for easy and unambiguous analyses.

Information which fills these criteria is likely to provide a good baseline and gives a chance for making good decisions, which leads to the wanted improvements. Providing this kind of information for management, it will similarly set another criterion for measurement. Generally the soundness of measure can be evaluated in terms of its validity, reliability and relevance (Suomala et al. 2007; Laitinen 1998). These three characteristics of good performance measurement are discussed next.

Validity means how well the measure is illustrating the phenomenon or concept that it should represent (Suomala et al. 2007; Laitinen 1998). Suomala et al. (2007) are demonstrating with case example how highly context-specific issue validity is. They emphasize that the requirements of the user should always take account when performance measure is constructed. Validity can be varying between operational management point of view and finance or accounting point of view. For improving the validity of measures, the causal relations of measure should be identified properly. (Suomala et al. 2007)

Reliability is describing how accurately indicator is measuring its object. This means that if measuring is repeated multiple times for the same object in the same circumstances, results should be same or as close each other as possible. (Laitinen 1998) Reliability of measure can be ensured and improved by standardizing measuring procedures, so that measuring is made same way every time. Without a reliable measure, the information collected will be not useful because it will include a lot of errors. (Laitinen 1998) If validity means that "we are measuring right things", reliability means "we are measuring it right way". These two are not automatically coming together, but for good measurement they both should be fulfilled. (Laitinen 1998)

Relevance measure is producing information which is valuable for decision making process and it has an impact to decisions. The more relevant the measure is the more it impacts on decisions. This relevance varies in time and decisions made, that means measures should always be context-specific. (Laitinen 1998) Some measures can be relevant for one decision making process, but not necessarily for another. When developing any kind of performance measure, these criteria explained above, should be keep in mind.

5.2 Measuring Cost of Poor Quality

Generally the goal of measuring CoQ or CoPQ is simply to identify how much an organization is currently pushing efforts on quality or wasting resources on poor quality. These numbers and figures are usually surprisingly high for managers, but guide them to recognize real targets for improvement, assuming the measurement has been trustful enough. (Kaplan & Atkinson 2014) The knowledge, how many poor quality costs are in the company is important for motivating all parties to make systematic improvements. Illustrating poor quality in monetary unit helps everyone to recognize the real consequences of their work and mistakes. Monetary units also help to prioritize different quality problems. (Sörqvist 1997a)

In literature, most of the authors discuss mainly how to define and categorize CoPQ, but how to measure these costs is usually less discussed (Mandal & Shah 2002). Sörqvist (1997a) is one of the few authors who are introducing method for CoPQ measurement. Methods of CoPQ measurement can be divided in two, based on principles they are carried out. "Deviation analysis" is observing existing defects and faults occurring in process and calculating cost for these. Another way is "best-in-class analysis", which is comparing the situation and costs to the best possible way to run the business, and difference of these is understood as a poor quality cost. From these two, deviation analysis is much more common and easier way to measure CoPQ. (Sörqvist 1997a)

Data collecting for deviation analysis it is natural to start from accounting systems, measuring and reporting systems, which already include useful information. Of course activities of poor quality should be defined and observed that collected cost information could be possible to allocate their sources. Identifying individuals and units which are concerned with poor quality activities can be a relatively easy way to obtain useful information. After documented information is collected, study continues with interviews which can be used for collecting supplementary and deeper information. Surveys can be also carried out for collecting information, especially in case of measurement of limited duration. After all necessary data has been collected, data should be analyzed and proposals for improvements established. (Sörqvist 1997a) In addition to this British Standard BS 6143: Part 2 (1990) is recommending following documents as valuable sources of information:

- payroll analysis
- manufacturing expense reports
- scrap reports
- rework or rectification authorizations/reports
- travel expense claims
- product cost information
- field repair, replacement and warranty costs reports
- inspection and test records
- nonconformance reports

Generally data collection should be carried out with good cooperation between accountants and quality managers for taking advance of the best of both sides (Williams et al. 1999; BS6143: Part 2 1990). However sometimes there's a risk that accountants and managers end up taking an adversarial position, rather than working in partnership. This is important because the key role of accountants has been reviewed in last decade. (Williams et al. 1999)

Sörqvist (1997a) is dividing the development of measuring system up into five phases: Phase 1: Proof of the need; Phase 2: Development; Phase 3: Training; Phase 4: Implementation and Phase 5: Measurement. These phases are including everything from management commitment until the operative use of measure. This model is providing basic process model for developing CoPQ measure, as well as for any kind of development process. After all, this model is very general view to CoPQ measurement, and clearly reveals the lack of detailed model for measuring CoPQ.

Like discussed earlier there's no established practices or clear procedures how to measure CoPQ, and that makes implementing of CoPQ measure difficult in companies. Usually there's a lot of disagreement over which costs should be regarded as poor quality costs. (Sörqvist 1997a) Sörqvist (1997b) is listing and explaining ten common difficulties or mistakes in measuring CoPQ in organizations. List is based on his CoPQ research in 30 Swedish companies also including successful and famous companies like Volvo, Sandvik and Ericsson. These ten common difficulties are:

- **Scope** is usually limited to covers only production operations.
- **The reason for measuring CoPQ** is not clear and connection to decision making and improvement activities is missing.
- **Definition** of which costs should be regarded as CoPQ is confusing and there's usually disagreement within a company.
- **Responsibility** of caused costs, and who should be "blamed" of poor quality costs is usually difficult decision.
- **Measuring techniques** are not established, which make it difficult and confusing to build up appropriate measurement system.
- **Management** should be involved and committed, which is not always the case.
- **Personnel** might be difficult to get involved to reporting poor quality cost arising from their own work. Sometimes there have been also protests by employees and trade unions against the measurements.
- **Accuracy** and especially lack of it, easily lead to the measurement being given low priority in management and not used actively.
- **Implementation** at the first attempt is essential, and if it fails, implementation again might be difficult to run successful because of already negative picture of what might be achieved.
- **Comparisons** between different companies is difficult because CoPQ varies widely, depends on type of the company. That's why it's difficult to compare CoPQ values with some reference value. (Sörqvist 1997b)

5.3 CoPQ measurement as a part of decision making process

When measures and key ratios have been developed and determined, it's not enough that numbers have been calculated out correctly. The way this information will be used is at least as important as developing good measures. (Neilimo & Uusi-Rauva 2010) Managers should remember that collecting quality cost information is useless if information is used in an ineffective way or not at all (Dale & Plunkett 1991).

Dale & Plunkett (1991) are grouping main uses of quality costs in three categories:

- Promote product and service quality as a business parameter.
- Give rise to performance measures and facilitate improvement activities.
- Provide the means for planning and controlling future quality costs.

When quality costs are promoted as a business parameter, it will raise quality aspects of the business in the spotlight, and will communicate the importance of quality through whole organization. The most common way to use quality costs is to measure performance and facilitate improvement activities. The main purposes for this use are to make comparison internally and externally, support decision making and to motivate whole organization. Comparison externally between different companies is mentioned to be difficult, because of lack of reference information and because of different measures. Quality cost-based decision making can be restricted to choices between competing cost reduction and quality improvements. Motivational purposes include display to every employee quality costs arising from their department. Quality costs can be also used for planning and controlling future quality, not only observing past or present. Measured quality cost information is base for this budgeting and eventual cost control, which many authors perceive as the ultimate objective.(Dale & Plunkett 1991)

The role of accounting information, like CoPQ in this case, in managerial work is too many times understood only related to specific decision making scenarios. However, managerial accounting should be more closely linked to management work and beyond specific decision making scenarios (Hall 2010; Socea 2012; March 1987; Preston 1986). Hall (2010) has researched how managers actually use accounting information and other information sources to make decisions, and what kind of information managers find helpful. Investigations have shown that even if decision making is undoubtedly important, actually it is relatively small part of managerial work and sometimes not that critical. Hall (2010) is highlighting three primary insights into how and why managers use accounting information in managerial work:

1. Accounting information is primarily used to develop knowledge of business environment rather than just an input into specific decision making scenarios (March 1987; Preston 1986).

2. Accounting information is just one part of the wider information portfolio which managers use to perform their work (McKinnon & Bruns 1992).
3. Accounting information is implicated in managerial work, rather in verbal forms of communication that through written reports (Ahrens 1997; Jönsson 1998). (Hall 2010; Socea 2012)

These three points are creating deeper understanding of relationship of accounting information and managerial work. Because managers are dealing with portfolios of problems rather than only one or two problems, it's clear that they can't have their own information source for every single decision making scenario. That's why accounting information should rather help managers to understand the environment they are working and making decisions. (March 1987; Preston 1986) For this reason, accounting information that is easily understandable and provides a common sense story of organizational performance, seems to be the most helpful for managers. Hall (2010) reminds that:

"Accounting information doesn't need to be elegant, complete or accurate to be useful for developing knowledge."

Sometimes, if accounting systems are too complex or not easily understandable, they might even reduce or camouflage hot spots that managers should be aware of and pay more attention. (Hall 2010) Also, because managers are using many different information sources to developing their knowledge, it's important that portfolio of these information sources is controlled. Some of this gathered information might be used, not for decision making, but to develop a context of knowledge and support decision making. This is why all these information should be considered and evaluated, not in isolation, but relative to other information sources in the portfolio. (Hall 2010; McKinnon & Bruns 1992)

When gathered the information is used to develop knowledge of the business environment, managers are able to make better decisions and take action even in sudden and unexpected situations. Because managers are not uninvolved and passive recipients of the messages that reports are carrying, they are reshaping and refining the raw information, most commonly in verbal ways. This is important issue, since it means that actual decision making is not only carried through formal reports, but rather through verbal communications between managers. (Ahrens 1997; Jönsson 1998) Thus, it's primarily how managers actually interpret and use information. (Hall 2010; Socea 2012)

As a conclusion, measuring quality costs is only a starting point for a systematic and continuous improvement process, but more importantly it will develop the manager's knowledge of their business processes, especially in the delivery chain. The main reason for measuring CoPQ is to figure out the current situation and point out the targets for improvements. Like mentioned before, measuring CoPQ is not improving quality alone, it's supposed to lead quality improvement process to the right direction, by developing the manager's knowledge. Shortly CoPQ measurement has a supporting and informative role in managerial work, and its role should be understood as background information source for knowledge development.

Above we have reviewed the most relevant theoretical background related to this research and now it's time to summarize them all shortly together. Based on the literature it's clear that customer needs should be the center point of quality, which can be understood as a fitness for purpose. In literature two different ways to think about cost of quality was introduced by Juran & Godfrey (1998). From these two, this research is supporting the idea where quality is understood as a freedom from deficiencies and thus quality should costs less. Therefore quality in this research can be seen similarly as Crosby (1986) has defined earlier, except the idea of free quality.

Quality should be managed comprehensively and it should exist whatever company does. Measuring and monitoring current quality is essential part in continuous improvement process of Total Quality Management. Quality can be measured many ways, like percent of defective, throughput yields, defects per unit or mean time to failure, which are good measures, but many times foreign for management and difficult to summarize in an organization-wide unit. That's why quality should be measured and communicated with the language of top management, money, to manage the business.(Harrington 1999; Feigenbaum 1991) One way to measure and categorize quality costs is to divide them in quality investments and cost of poor quality. Quality investments are those prevention and appraisal activities invested to good quality, when cost of poor quality is describing failures of these investments. When quality costs are measured like this, it gives better perspective for management to recognize inputs and outputs of quality in monetary language. Thus meaning of cost information for quality management is basically to concretize the quality in monetary units and so get the attention of managers.

6. DESCRIPTION OF THE CURRENT SITUATION

This chapter will take a closer look at the current situation in the case company. This will include comprehensive process description of delivery chain and discussion of the current quality measurement used in case company. Therefore the purpose of this chapter is to create a baseline for following empirical study and development of CoPQ measurement model in the following chapter. Information has been collected from various internal sources like documents and by interviewing responsible managers.

6.1 Delivery process of the case company

The process description will break down the delivery process from mill to customers, also covering the return handling process for defective products. This division of delivery chain in parts is made for clarifying and sharing responsibilities and activities of each part. Moreover this structure will be used to develop CoPQ measurement model in the following chapter. These five parts of delivery chain are Order handling, Mill, Leg 1, Leg 2, Leg 3 and external converting; every one of them is responsible of defections caused by their poor quality. The logistics chain is divided in three parts: Leg 1, Leg 2 and Leg 3, for deeper understanding of their quality and because of the different kinds of operations. By dividing delivery chain in parts like this, it is possible to allocate cost of poor quality to their root causes and find which part is generating costs and defections. Analyzing these parts one by one, targets for improvements can be recognized.

In this thesis the delivery chain of the case company is limited to start from order handling and ending to return handling process. Because this thesis is focusing on CoPQ in cartonboard deliveries, it is natural that in-bound supply chain before mill is left outside of this research. Why order handling and return handling process are included, can be justified through their impact to poor quality in the delivery process. Mistakes and poor quality made in order handling process, like mistakes in order specifications, might have a huge impact to poor quality of delivery chain, but too many times these mistakes are allocated to mill, not to order handling function. Similarly return handling process is many times understood and managed as an additional part of supply chain which should avoid but which generate costs anyway. These costs caused because of mistakes in delivery chain should be also allocated to their real root causes, not to some additional part of supply chain. Theoretically the return handling process can be understood as poor quality activity as a whole, because if quality would be perfect this function would disappear. The delivery chain of the case company, as wide as it is understood in this research, is illustrated in figure 16.

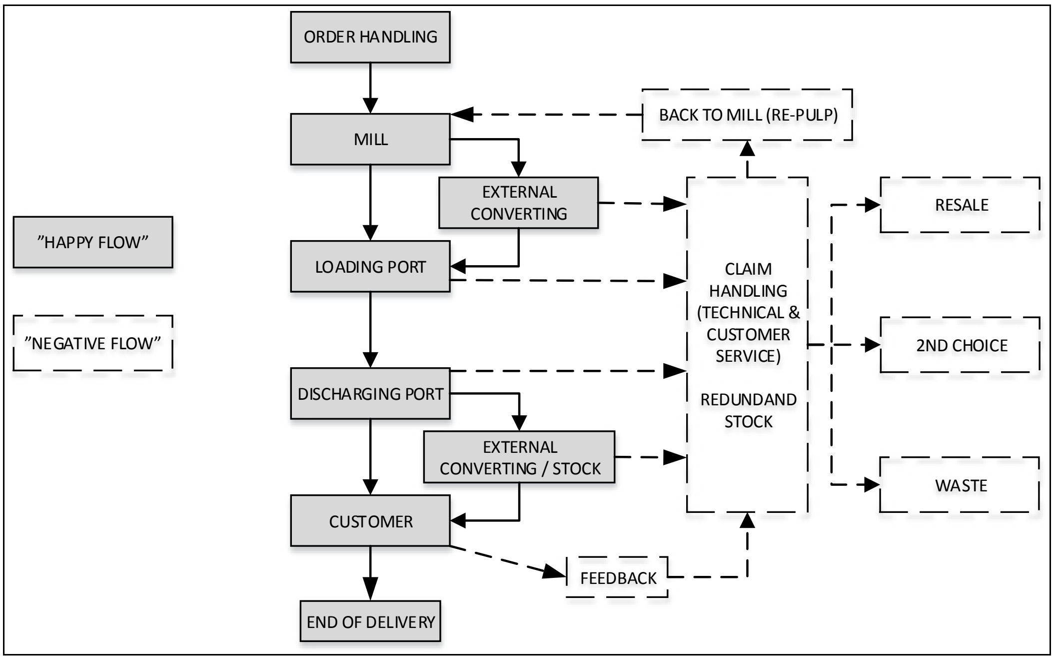

***Figure 16** Delivery process and return handling process of cartonboards in case company.*

Deliveries are understood to start when order handling function is placing an order to the mill and ending when customer receives a product. This delivery chain, when everything goes as planned, is called as "happy flow", and it's illustrated with grey boxes in figure 16. In case of defective product, so called "negative flow" will expand delivery chain to cover also return handling process, including claim handling, resale, 2nd choice & waste selling and, in some cases, returns back to mill. In ideal situation this "negative flow", illustrated with dash lines in figure 16, should not even exist. In this ideal situation, if there's no any defection, after customer order has placed successfully product will be manufactured in the mill for required specifications. In cartonboard business it is typical that there's almost as many specification as there are customers, so products are actually highly customized for customer's need directly at the mill or later within delivery chain. One good example of this customization is sheeting process, which can be done already at the mill or later by using external converters, if the customer has ordered a sheet product. Basically products can be sold and transported in sheeted form or reels. Because production units of the case company are all located in Finland and Sweden, the first logistics leg is carried by trucks or trains to loading ports, depending on the destination and routing. Shipping between loading port and discharging ports, located in Central Europe is separated to its own logistic leg 2 in this research. After discharging port products have been delivered to customer sites, stored in common stocks or sheeted by external converter. It is worth mentioning that the case company doesn't own any logistical equipment or warehouses, which means, all logistics operations, except planning, coordinating and managing, are outsourced to logistics service providers.

If some defections occur in delivery chain, corrective and extra activities will take action. All these acts, could be avoided if no defections would occur in deliveries, and so they are activities of poor quality. These exceptional actions are illustrated in figure 16 with dash lines, as mentioned before. These dash line actions take place when delivery has been defected and it's not possible to deliver the product to original customer anymore. Practically this means returning product back to mill or sell it as a 2nd quality. These two options have their own pros and cons. If product will be carried back to mill the logistics and administration costs will increase a lot, but on the other hand product can be used as a raw material in manufacturing process. The specialty of cartonboard manufacturing process is that pulp made of scrap is actually needed for good quality of cartonboard. Benefit of this reused pulp is that it creates lightweight and air-filled structure into middle layer of cartonboard. Usually scrap from the mill is used directly for this purpose, so it isn't always necessary to bring scrap back to mill from far away. However sometimes there's also a lack of this reused pulp and then additional scrap from outside of the mill is needed. Alternative action for returning is selling product as a 2nd quality or waste. In this option extra costs are minimal compared to the returning option, and usually all the costs can still be covered by selling price. However, at least some part of profit will be lost, because of lower selling price. Also, selling products as a 2nd quality includes always risks of losing reputation, trademark piracy and distortion in market prices. Generally it isn't possible to say which one of these two options is always better. Decisions are always case-specific, and based on comparing total costs of both options. Sometimes it might be better to sell 2nd quality, while sometimes returning to mill is maybe a less costly option. For better decisions related to this issue, this master thesis will provide a deeper understanding about the total costs of these two options for managers.

These two corrective actions, described above, are of course taking place only in a case where the defective product can't be fixed or handled anymore in a way that it could be possible to deliver it to the original customer. When finding out all the poor quality activities within this delivery chain, it's good to remember that all extra, unplanned, activities needed for securing original delivery to original customer, should be counted. These will include for example repairing or re-packaging activities for damaged products and priority logistics operations for late deliveries. Shortly, all exceptional activities from the original streamline, "happy flow", of delivery chain can be understood as poor quality activities, since they are not adding value and could have been avoided by doing things better in previous stages.

Next all the responsible functions will be introduced in more detail and their role in the delivery chain will be explained. Every function is running various activities, value-added and non-value-added, which are using resources. These activities and resources will be also introduced and illustrated through real-world example case, focusing on non-value-added activities. These functions, activities and resources will be used later for measuring CoPQ in case company.

Order handling

Order handling process is covering the sales function. It is including traditional selling operations, but in this case even more order handling process. Order handling processes have been included in the delivery chain, because it is basically the first place where case company can make mistakes which are affecting further in the delivery chain all the way until customer. Shortly the order handling process is covering interaction with the customer and supporting customer to find right product for their specific needs. When the customer's needs have been recognized and the customer has ordered products with the right specifications, order information should be transferred to the production system correctly. Typical faults made in the order handling process are wrong specifications or wrong instructions. These failures might be caused by human mistakes or just because personnel mistakenly sold the wrong product or might be even that the customer didn't know what product specifications would have been right for his purpose. Even if failures made in order handling might be relatively small, they might have huge consequences. This is because products which have been ordered wrong are actually very difficult to catch before the customer. Wrong order specifications or amounts usually leads to situation, where all internal inspections see the product as perfect, but finally customer realize that product is wrong for his purpose. Of course in these cases, it's also customers fault if they have ordered wrong product, but after all costs of that will be paid by case company and that's why case company should always be sure the right product has been ordered.

Manufacturing

As discussed before, the case company has production in five locations in Finland and one location in Sweden. Because huge volumes and global markets, delivery network of the case company is quite complex and contains many different kinds of situations. This is why in this master thesis the scope of the research has been chosen to cover only deliveries from one cartonboard mill, Äänekoski mill. This decision will make research more focused and it let us go to a much deeper level. Also CoPQ model created in this scope can give information generally for decision making situations wider within company. Äänekoski mill have been chosen for this research because its product mix is including only cartonboards, as we saw earlier in table 2, that makes the model more simple, but at the same more valid. One other big reason for choosing Äänekoski, was their own sheeting function. This own sheeting line is included to the costs model and it can be compared to external sheeting operators. Choosing between internal and external sheeting operations has been realized to be one relevant decision making situation in case company.

Leg 1

In this research the logistic chain has been divided in three different legs for sharing responsibilities and making a deeper analyzes possible when allocating costs of poor quality. Similarly it will help to focusing targets for improvements if needed. This division to three different legs is already following used procedure in case company, which make it easier to integrate CoPQ model to existing management system.

Leg 1 is naturally covering the first leg after production in Äänekoski mill and ending at the customer or at the loading port in case of exporting outside of Finland. As the CoPQ model was limited to cover only one mill in manufacturing, also logistic chain is limited to cover all deliveries from Äänekoski mill to Hanko port in Southern Finland. This means that CoPQ model in this research will exclude domestic markets and other loading ports in Finland. From Äänekoski to Hanko products are carried mainly by rails, but also by road transportation. As mentioned before, in Äänekoski there is own sheeting function, so products can be carried from mill in form of reels or sheets. However Äänekoski sheeting function doesn't have a rail connection, which makes it inconvenient to carry sheets by train, so sheets must be carried by trucks even if it's a little bit more expensive. By contrast, from the cartonboard mill there is a rail connection, and naturally most of reels are carried by train from Äänekoski. Only some exceptions and faster deliveries might be done by trucks. In Port of Hanko reels and sheet pallets are unloaded from trucks to sto-ro (stowable ro-ro) trailers which then will be moved into the ship and loaded there. This sto-ro transport mode is combining benefits of bulk cargo and roll-in-roll-out cargo. Sto-ro allows shorter loading time and better payload at the same time. In CoPQ model costs of leg 1 will be generated by transportation from Äänekoski to Hanko, so loading and handling costs in port will be included to next leg 2.

Leg 2

Leg 2 basically covers all shipping operations from loading port to discharging port. As leg 1 ended up to Port of Hanko, it will be the starting point for this leg 2. In this CoPQ model leg 2 will cover all deliveries from Hanko to Antwerp or Lübeck. This means that whole model will cover markets of Central Europe, which is one of the biggest markets. Costs of leg 2 are generated basically by handling, loading, shipping and unloading costs as well as all additional costs caused by fixing and repairing damaged products. Because the case company doesn't have any transportation equipment or warehouses, all logistics operations are bought from an external service provider. Usually these costs are negotiated in annual contracts which include oil price corrections. Warehouse contracts usually include some warehousing days, and if products are staying longer, it will pay more.

Leg 3

Leg 3 is the final leg from discharging port to customer, so in this case, it will cover all deliveries from Ports of Antwerp and Lübeck to customers, directly or through distribution centers. In this last leg deliveries are naturally carried by trucks to customers, but sometimes also by trains if deliveries are going through a distribution center. Because the CoPQ model covers only deliveries which are carried through Antwerp and Lübeck, it also limits market area to cover France, Netherlands, Belgium, Germany, Switzerland, Austria, Czech Republic, Hungary, Italy, part of Spain and part of Poland. So, logistic leg 3 will include all deliveries from Antwerp and Lübeck to these markets.

External converting

As mentioned before, for sheeting operations the case company has many options. Basically sheeting can be done internally in own sheeting function at Äänekoski mill or externally in Finland or in Central Europe. This CoPQ model will include own sheeting in Äänekoski and external sheeting in Winschoten, as well as already divested, own sheeting operation in Gohrsmühle. Having both internal and external converting operations included in cost model will give us chance to compare these operations to each other and increase our understanding of converting operations. Converting costs include the costs paid for converting service, transportation to converting and further to customer as well as costs of waste arising from converting. Converting waste arises from sheeting operation when some parts have to be cut off, but also because of poor quality when something goes wrong. That's why it is questionable which waste is just normal operational trim waste and which one because of poor quality, especially when these two are not separated in statistics.

Technical and Customer services

Technical service and customer service are functions which are strongly related to CoPQ because they are mainly handling all customer feedbacks and claim notifications. Basically these two functions are operating closely in customer interface, and that's why they have strong impact to CoPQ. Currently the line between these two is not that clear what have made roles of these operations and serving customer overall, quite confusing. Also communication and co-operation with sales network is not working as it should. For these reasons, at the moment there is another project going on in case company for clarifying and standardizing tasks. Basically the difference between technical and customer service is that technical service is supporting the customer with any technical challenges and helps the customer to choose right product for their specific needs. Customer service is more generally supporting customers in any kinds of issues and many times customer service personnel is the first contact for the customer. Both of these functions are handling claim notifications, technical service more technical and product related claims, when customer service maybe more internal and service claims. Claim handling process should be only one little part of their job, but unfortunately nowadays significant portion of total resources is used for this non-value added activity. Vice President of technical customer service estimated that even 60% of total resources are wasted to claim handling process, when other activities used resources as follows: Trials 25%, Technical sales support 10% and Customer training 5%. As we can see, these activities which case company is using less effort now are actually those preventive activities to avoid failures and mistakes. Similarly in customer service, the vice president was really worried about the current situation, where claim handling tasks seems to be the lasts in to-do-list of personnel, and too many times customer has to wait for solution of the case company because of this.

In scope of this master thesis topic, most interesting part of technical and customer service operations is of course how they are handling claim notifications. Figure 17 is illustrating simplified procedure of claim handling process. As we can see there are many different personnel involving and many different tasks to be done before the claim is solved. Usually process starts when customer or personnel before the customer recognizes the defective product and informs the closest personnel of case company, usually in sales, technical or customer service functions. When a claim notification has been opened, claim handling and investigation start, which will usually include sending evidence (pictures, samples etc.) to technical service and responsible mill. In some cases visit to customer's site might be needed if claim is large and expensive enough. The handling process will end when notification is closed and all corrective acts have been done. These corrective acts depend of the case but usually they might be for example repairing or fixing products, sending replacing product or crediting feedback to customer. Resolution time for one claim is varying from few days to over one year, when average is around 30 days. This is natural because there are so many different kinds of claims to handle. However, most of the claims are still clear and relatively small ones and actually whole handling process might be easily more costly than credited amount in these cases. That's why case company has recently changed the policy, which allow resolving small and clear cases directly "at the field" and the first contact person can make the decision in these cases.

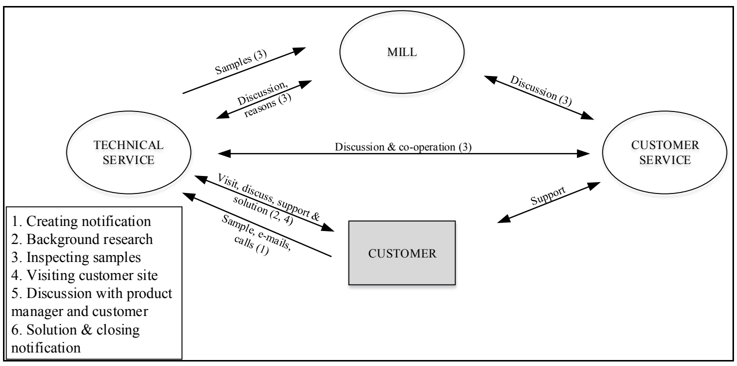

Figure 17 *Communication and actions between TS, CS and Mill in problem solving process*

Return handling process

Return handling process is taking place when something goes wrong and for one reason or another product is not following originally planned delivery anymore. In figure 16 this process have been illustrated with dash lines and called as “negative flow”, because it’s more or less “rescue operation” for an earlier made mistake, and definitely not the desired situation. Common reasons for returns are quality issues, damages, wrong specifications, wrong instructions, cancellations or any other reason which makes the original delivery not possible. These unsuitable products can be moved to return handling process in any point of the delivery chain, but too often products are returned from customers. When product is entering the return handling process there’s basically two options: resale it or return it back to mill. Resale can be selling with prime price, if the product is still prime quality. This is the case usually if product has been returned because of wrong specifications or wrong instructions. Unfortunately, more often these products are returned because of quality fault or damages, and only option is to sell with lower price, as 2nd quality or waste. Selling as 2nd quality will usually recover committed costs but at the same time it contains many risks, like trademark piracy and market distortion. This is why case company tries to avoid selling as 2nd quality and if they have to sell they will sell only to trustful traders, so that they can be sure where and for what purpose the product is really going. Figure 18 is explaining the procedure of return handling process and also wasted resources and risks related to every stage are illustrated.

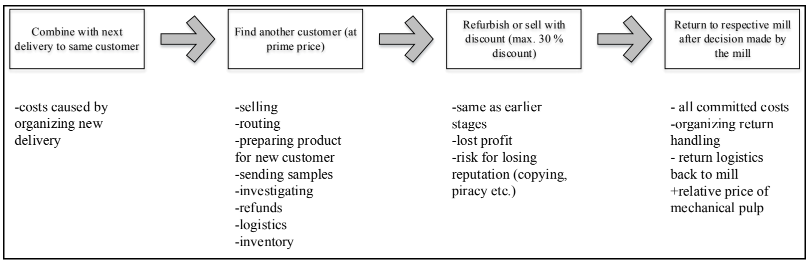

***Figure 18** Action steps of return handling process and poor quality activities related to every step.*

In figure 18 we can see that resale to same or another customer with full price or with discounts is usually the first option. If selling is not possible, then products will be returned back to mill and used as a raw material in manufacturing process. As mentioned earlier, re-pulped raw material is needed for manufacturing high quality cartonboard, what can be counted as positive side of back to mill returns. However the logistic chain back to the mill costs money and requires extra labor work for organizing and re-routing deliveries back to the mill. Usually return deliveries are collected in discharging ports, in this case it means Antwerp and Lübeck, where bigger batches are carried back to Finland few times per year. Typical decision making situation related to return handling process is decision between resale and return back to the mill.

6.2 Current CoPQ measure in case company

Currently case company is measuring CoPQ through credited customer feedbacks which are allocated to each responsible mill. This is very simple, easy and that's why it is also a common way to the follow level of quality and costs of quality. The current quality measure tells managers how the level of quality has developed in various time periods and how much feedback has been credited and why. However, this kind of quality cost collection leads to a situation, where mills are profit centers which collect all quality costs. Other quality costs caused for example by a damaged product in transportation is included into logistic costs, where it will be mixed with operational costs. When only mill is responsible of quality costs, it might be hard to motivate other parts of delivery chain to reduce these costs, because they are not responsible of them. Currently in the case company more or less managers know, there are many poor quality costs inside the delivery chain. However, because nobody has measured CoPQ of deliveries yet, it's really hard to manage and improve quality only with beliefs. Like that old phrase, mentioned beginning of this master thesis, tells: If we want to improve something, first we need to measure it.

Collecting quality data, in the case company, is a continuous operation and it's organized through ERP-system. Basically always when something happens in delivery there will be mark into this system, and so it's also with claim notifications. Always when internal or external actor realized that there is something wrong in the delivery, a claim notification will be made by closest sales, technical service or customer service personnel. After this the same person who has opened notification should also investigate and handle it until the claim is solved and closed. In the case company all faults have been categorized in four different groups: quality-, internal-, external- and service faults, which are illustrated in figure 19.

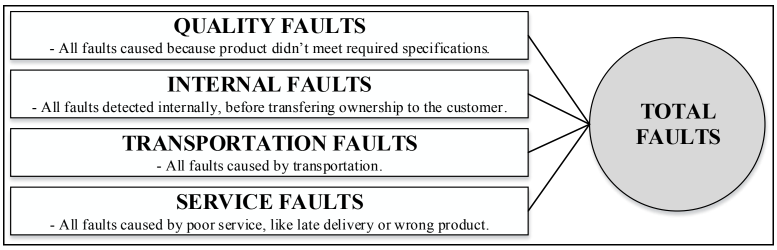

Figure 19 *Currently used categorization of faults in the case company.*

Quality faults are directly related to product quality and so they are usually always caused by mill. Because products are packed after production, it is not really possible to inspect product quality anymore after the mill. This leads to situation where too many times the customer is the first one who inspects the product quality after quality inspection at the mill. It's clear that the customer should not be the one who recognize quality faults; because in that case all possible costs have been already committed and the case company will also lose its reputation. Sometimes it might be possible to call back products from the logistics pipeline before the customer, if laboratory tests have caught some quality issue. However, still too often the first example is the case.

Internal faults are detected internally before transferring ownership to the customer. These faults usually cost relatively less than quality faults because defected product didn't get to the customer yet.

Transportation faults are caused by transportation. Usually these costs are damages in package or product which have been caused in some point of transportation, mostly in loading or unloading products to or from ship.

Service faults are basically every other faults which are not included in the three other categories. Usually service faults are late deliveries, under/over deliveries, wrong instructions or wrong specifications.

Currently these quality costs, or poor quality costs, are followed quarterly with summary report from mills. Basically that report is summarized from internal ERP -system and it includes costs and number of credited customer feedbacks and causes for them. Report is collected at mill and shared quarterly for all responsible managers all the way to top management level, which tells the importance of this report. Report is used for follow and control quality, and if something unusual happens in figures, management should start corrective actions. Report also tells something about customer satisfaction in number of complaints. However the case company has realized from these numbers, that usually when supply is high compared to demand, also customer complaint rates are increasing. This means there are many different factors, not only product quality, which affect to these numbers. Overall current customer complaint measure is very simple and it tells level of product quality in time period and it also gives information about quality trend. Table 6 is illustrating the currently used report which is summarizing credited customer feedbacks. Data in this table is limited to cover same markets and same mill, what will be used later for new CoPQ model, so this table can be used as a baseline for new cost model.

Table 6 *Summary of current customer complaint report used for measuring poor quality costs in case company.*

ÄÄNEKOSKI MILL		
Complaints which have came to the system during 7/2014 - 7/2015	Nr	EUR
COATING DEFECT	32	6,5 %
CONVERTABILITY, HANDABILITY	3	3,5 %
CURL AND STABILITY	11	10,6 %
DUST AND HICKIES	21	11,5 %
FINISHING PROBLEMS	19	8,0 %
MECHANICAL DAMAGES OF UNPRINTED BOARD	18	16,4 %
PRINTABILITY AND VARNISHABILITY	8	7,6 %
SERVICE FAULTS	50	18,3 %
STRENGTH AND RELATED	13	11,0 %
VISUAL DEFECTS OF UNPRINTED BOARD	7	6,4 %
Grand Total	182	100,0 %
Credited EUR / Turnover (%)	0,23 %	

As we can see from table 6 above, measuring CoPQ is currently strongly focused to follow quality faults caused by the mill. This is natural when remembering that the case company is operating in manufacture intensive industry, and production units are cost centers. However, as mentioned earlier this current way to measure CoPQ leaves a lot of relevant poor quality costs in shadows, especially those costs arises after mill, in delivery chain. Similarly, wasted labor costs used for poor quality activities are not measured at all. Sure is that these costs, currently not counted as poor quality costs, are realized within other operating costs, for example logistics and labor costs. But also the truth is, that as long as the case company is not seriously considering these costs as a wasted poor quality costs or analyzing the root causes for them, those costs will also appear in the future.

7. MEASURING COPQ IN CASE COMPANY

This chapter will introduce and explain the new model for measuring CoPQ in deliveries of the case company, how it was created and what it's included. The basic idea is to see poor quality costs wider and in a more holistic way than currently in the case company. This more holistic view is not only limited to poor quality costs of products, but covering also extra logistic costs of returns back to mill, failures in the delivery chain after the mill as well as non-value-added labor activities and lost opportunities. This new model will give executive management the ability to monitor delivery chain and poor quality closer than before, and let them make targeted decisions for improving total quality of deliveries.

Because CoPQ model would have been easily expanded too huge in amount of data, there was need for making some limitation and finding a right scope for CoPQ model. This was also needed, when remembering limited time period for this master thesis project. This scoping also allows this research going deeper than in general, companywide level could have been possible. The scope of this research and CoPQ model decided to cover one cartonboard mill in Äänekoski and its deliveries to Central Europe markets. Delivery chain, markets and logistics legs covered in this research are illustrated with map in figure 20.

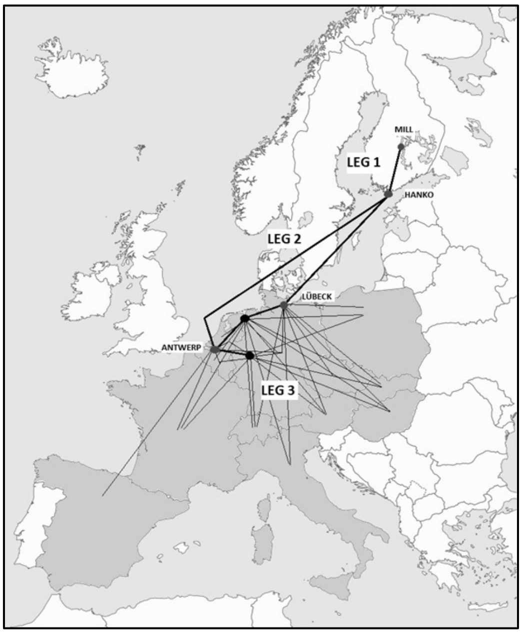

Figure 20 *Delivery chain, locations and markets covered in new CoPQ model.*

In figure 20 black dots are presenting all locations involved to this CoPQ model. These locations are Äänekoski mill, Port of Hanko, Lübeck and Antwerp as well as external converters in Winschoten and Gohrsmühle. Converting in Gohrsmühle has been closed down during this project, but it was decided to keep it in this model because it was still operating in the observation period of this research. By choosing these locations in the new CoPQ model, all possible functions and activities are included in the model. When all activities are covered with this model, it gives a more holistic view to the delivery chain and it provides information which can be applied for other delivery chains with the same activities. By choosing this kind of delivery chain to model also provides much wider knowledge to managers and let them use it, not only for one decision making situation, but for many different purposes.

In figure 20 dark grey colored areas are market areas which are covered in this CoPQ model. This Central Europe's market area is very significant and that's why also natural choice for this model. Market area is defined as all deliveries which are delivered through Antwerp or Lübeck, so the map in figure 20 is only suggestive view of exact markets. Still there's no big difference, when only differences are in Spain and Polish markets which are also served through ports in Poland and Spain. Otherwise all markets are completely covered, what it comes to products of Äänekoski mill. Antwerp and Lübeck were taken into model because then model includes sea transportation and also external converting in Winschoten and Gohrsmühle. This decision was supporting that basic idea to cover all possible activities within this one model. Loading port in Hanko was then obvious to take into the model since it's the loading port for vessels carrying Äänekoski products to Antwerp and Lübeck. In the map the delivery chain is illustrated with lines between these locations.

Another limitation for CoPQ model is related to observation period. The chosen observation period should be enough long for reliable and valid information, and for minimizing error values. However, for practical reasons observation period must be limited enough short or otherwise the amount of data might be exploded too big to handle. Especially huge amount of data is arising from logistic data, when costs data is including every activity for every leg separately. This is why in this research the main observation period decided to keep in one year, starting from 7/2014 and ending to 7/2015. This is time period realized to be enough compact for manage all the data, but still enough long for reliable data mass. This main observation period is used for monitoring the total costs of poor quality in CoPQ model for this time period. The reason why observation period is starting and ending in middle of the calendar year is, because that's the latest possible data and so it's more valid for use. Addition to this main observation period of one year, the logistic cost structure is built up using two year history data from 7/2013 to 7/2015. This is possible because new CoPQ model is based on two dimensional structure of ABC, introduced earlier by Tsai (1998), and costs of resources are first allocated to activities and again to cost objects. There was need for creating an accurate cost model for logistic costs and that's why 2-year time period was more relevant for use. This 2-year time period is used only for modelling actual average costs for every logistic costs for every single leg, which allows managers using also this logistic model for analyzing different scenarios for decision making. In CoPQ model these 2- year average costs are used with actual back to mill returned volumes for allocating actual total costs of returns in observation period.

As already mentioned the CoPQ model is adapted from, and using similar structure as Tsai (1998) introduced earlier in Chapter 4.3.1 ABC Models. The basic idea of model is simply to allocate costs of resources wasted for poor quality to poor quality activities by using suitable resource drivers. After resource allocation, costs of poor quality activities are allocated to cost objects, which are causing these activities, by using activity drivers. In figure 21 general and simplified structure of new CoPQ model for case company is illustrated. In the outermost in figure are resources wasted because of poor quality which are allocated to poor quality activities in the middle section. Finally these costs of poor quality activities are allocated to responsible parts of delivery chain, and summarized to complete CoPQ model in the center of structure.

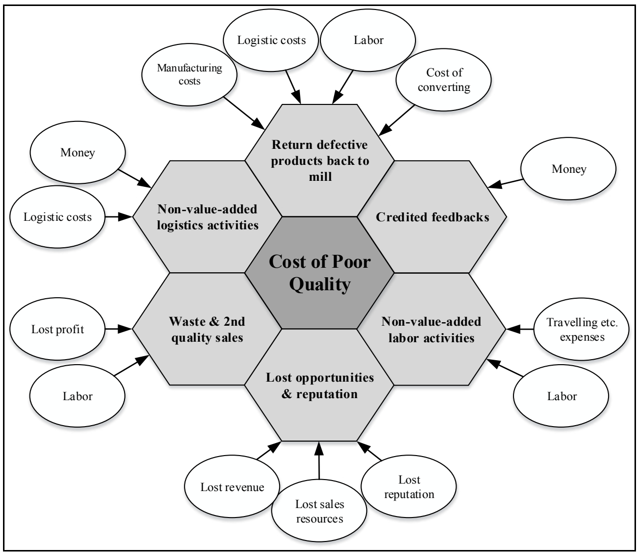

Figure 21 *Simplified structure of new CoPQ model.*

In the spotlight of this CoPQ model are poor quality activities which were the starting point for whole model. These are activities which are not creating value for customer and in some cases they might even destroy the created value. In cartonboard deliveries of the case company following poor quality activities came up in this reasearch:

- Credited feedback for customers.
- Returning defected products back to mill.
- Failure and non-value-added activities in logistic.
- Waste & 2^{nd} quality sales process.
- Non-value-added labor activities.

- Lost opportunities and reputation
- Faults in external converting

These seven activities are actually poor quality activity groups, because they contain many activities of poor quality, which will be introduced closer when allocating activity costs later in this chapter. These poor quality activities are using resources like money, logistics, machines and labor. Some of them can be directly allocated to activities, when some of them have to allocate by using resource drivers. Similarly costs of these poor quality activities are allocated to a responsible department, or part of the delivery chain. The parts of the delivery chain are Order handling, Mill, Leg 1, Leg 2, Leg 3, External converting and Technical & Customer service. These six functions are involved more or less to delivery chain and so they are also responsible of poor quality activities and costs.

The costs of poor quality activities are allocated to responsible departments using two different principles. Basically feedback costs are allocated for department which originally was the reason for feedback. This means that even if currently there's no feedbacks allocated for example for order handling, they are still causing some feedbacks by making mistakes, like giving the wrong order instructions, which should be allocated to them in new CoPQ model. This different way for allocating feedback costs helps to find and point out the root causes for feedbacks. Only feedback costs will be allocated by root causes. Unlike feedback costs, all other poor quality activities are allocated for responsible parts by activity drivers.

The following subchapters are introducing all poor quality activities and resources they used, and especially how resource costs have been allocated to activities and activity costs to responsible parts of delivery chain. In the end of this chapter all costs will be summarized to one complete CoPQ model. Because we are talking about cost information which is naturally sensitive for case company, all costs will be illustrated in percentages of total values.

7.1 Allocating feedback costs

The first introduced poor quality activity is credited feedback costs. These costs are natural to be introduced first, since we remember from previous chapter that these costs are only poor quality costs currently measured in the case company. As discussed earlier, currently feedback costs are measured through quality costs reports of mill. Thus only product and service quality related feedback costs are included to that report and all of them are allocated directly to mill. Basically this means that mill is the only quality responsible part in the delivery chain.

In new CoPQ model feedback costs are allocated to each responsible part of the delivery chain. Now feedback costs are allocated to root causes, what is more fair, realistic and more over gives the right information about operational quality in these departments. Table 7 is summarizing the number of all received feedback notifications and credited amounts to customers in euros. The number of notifications includes all notifications, even if they were not credited. Notifications are categorized in four groups: Product-, internal-, service- and transportation feedbacks, as introduced earlier. When comparing percentages in the number of notifications and credited amounts, we can see that internal feedbacks are clearly the biggest group in number of notifications, but in credited amount product feedbacks is the biggest. Reason for this is that internal feedbacks are made internally and are not usually credited to the customer or service providers.

***Table** 7 Number of claim notifications and credited amounts in observation period.*

Credited customer feedbacks				
Number of Notifications	**Number**	**%**	**€**	**%**
TOTAL	580	100 %	XX,XX	100 %
Product Feedback	149	26 %	XX,XX	68 %
Internal Feedback	300	52 %	XX,XX	16 %
Service Feedback	81	14 %	XX,XX	15 %
Transportation Feedback	50	9 %	XX,XX	1 %

The resource credited feedbacks are using is money. The cost of feedbacks is wasting money caused by poor quality, and these costs can be directly allocated to root causes. The cost data for feedback costs is collected from feedback cost report from ERP. There was need for filter raw data to get real credited amounts. Values which are filtered out from this model were cases where credited amounts have been debited back to the case company, and cases where the customer have been credited for a returned product which was still good for sale even at full price. By filtering this kind of data out, final data includes only those cases where the customer has really been credited by the case company and customer has kept the product.

7.1.1 Internal Faults

As discussed in theory part in chapter 4, failure costs in CoPQ model can be divided in internal and external faults. Internal faults have been recognized before transferring ownership to customer and external faults are detected by customer. The next feedback costs are divided in external and internal failure costs and allocated to their root causes to responsible departments.

From current feedback categorization of the case company only **internal feedbacks** are actually internal faults. These faults are caused because of internal failures but also detected internally before customer. This means the consequences of these faults are smaller than external ones. In case company internal feedbacks can be broke down to activities as follows:

- Handling & transportation damage
- Loading error

- Warehouse operator causing idle time
- Wrong transportation mode, type or poor quality
- Other external cause

The list is generally longer but this list is covering all those activities occurred in scope of this research. These failures are clearly happened in internal operations. However "Other external cause" can be confusing, but external in this case means internal failure made by external service provider. Since we remember that the case company don't have their own logistics operations, it's natural that internal failures include failures made by external actor. For same reason many transportation or internal failures are first credited to customer and then external actor have been credited same amount to the case company. In this kind of case, the amount the case company has received is filtered away for making sure the cost model is including costs of all failures. This is also underlining case company's responsibility of all failures in its delivery chain, even those made by external service provider.

Allocated internal feedback costs are illustrated in table 8 as a percentage of total feedback costs. Allocation was based on locations where notifications have been done. Usually in case of internal failure the mistake has already done at a previous stage before the place where notification has done. For this reason feedback costs are allocated to leg before place of notification. Practically, as in table 8 is shown, failures detected in Hanko (HKO) are allocated for leg 1, notifications from Antwerp (BEAN) and Lübeck (DELS) are allocated for leg 2 and others for leg 3.

Table 8 *Allocation of internal feedback costs.*

Internal Feedback			
Place of notification			**Credited**
Plant	HKO	LEG 1	0,3 %
	BEAN	LEG 2	3,9 %
	DELS	LEG 2	11,1 %
	OTHER	LEG 3	1,2 %
Total Cost			16,4 %

Responsible Party	**Assigned Cost**
LEG 1	0,3 %
LEG 2	14,9 %
LEG 3	1,2 %
TOTAL	16,4 %

Allocated internal feedback costs seems to be highest in leg 2, which is natural when we remember that leg 2 is covering loading- and discharging ports as well as sea transportation. Ports are usually handling products many times and that's why it's clear that probability for damages is also higher there.

7.1.2 External Faults

External faults are result of failures detected by external customer, and that's why these feedbacks are also more expensive and more violent for the reputation of the company. In the case company external faults contain product-, service- and transportation feedbacks.

Product feedbacks are customer complaints, mostly related to quality issues in product specifications. Only these quality faults are traditionally understood as a quality costs, because they are related to technical quality features of product. These product quality feedbacks include following quality faults:

- Coating defect
- Convertability & handability
- Curl & stability
- Dust & hickies
- Finishing problems
- Mechanical damages of unprinted board
- Printability & varnishability
- Strength and related
- Visual defects of unprinted board

Like it was the case with the internal faults earlier, this list is covering only those quality problems occurred in observation period of this research. Like we can see all these product related quality faults are strongly related to technical features of product and that's why only reason for these faults are in the mill, more closely in cartonboard machine. Therefore it's easy to decide to allocate all of these costs of poor quality directly to responsible mill, Äänekoski mill in this case. Summary of allocated product feedback costs in percentage of total feedback costs is shown in table 9.

Table 9 *Allocation of product feedback costs.*

Product Feedback		
Total Cost (% of total feedbacks)		67,6 %
Responsible Part	Share	Assigned Cost (% of total feedbacks)
Mill	1,00	67,6 %

Notable in these product feedback costs is that now the mill is carrying smaller amount of feedback costs than in current quality cost measure in the case company. This is because only product quality costs, which are clearly caused by mill, are now assigned to mill.

Service feedbacks are results from failures where product itself has been perfect, but there have been something wrong in service, like late delivery. In observation period in this research following poor quality activities occurred:

- Customer errors
- Document errors
- Late delivery
- Under/over delivery
- Poor packaging

- Wrong instructions
- Wrong product specifications
- Others

Service feedback costs are quite tricky when finding root cause for them, because they are detected by customer and the reason for failure can be sum of many factors, not only one. For example the delivery can be late because of one or many, maybe even all parts of delivery chain failed to deliver products on time. However from list above poor packaging is caused by mill and wrong instructions is caused by mistake in order handling process. These two poor quality activities can be assigned directly for responsible parts. All the rest activities are not that clear and that's why those need to be allocated to all functions, except order handling, which can be ruled out. Allocated service feedback costs are shown in table 10 as a percentage of total feedback costs.

Table 10 *Allocation of service feedback costs.*

Service Feedback	
Poor packaging	0,3 %
Wrong Instructions-Sales	2,3 %
Common faults	12,4 %
Total Cost	15,1 %

Responsible Part	Share of common costs	Assigned Cost
Sales	0	2,3 %
Mill	0,25	3,5 %
LEG 1	0,25	3,1 %
LEG 2	0,25	3,1 %
LEG 3	0,25	3,1 %
TOTAL	1,00	15,1 %

These service feedback costs which are now allocated to their root causes were earlier all assigned to mill only, like we can see in table 6. Now some parts of those feedback costs are shared also for other parts of delivery chain, which represent the real situation better. For example all late deliveries are not necessarily caused by the mill only.

Transportation feedbacks are naturally the result of failure or accident happening during transportation. Following poor quality activities related to transportation feedbacks occurred in observation period in this research:

- Handling & transportation damage
- Traffic accident
- Others

Even if internal and transportation feedback activities are close to each other and even a few of the same activities exist in both of them, the difference is that transportation feedbacks are externally detected. Therefore basically the same mistake can be internal or transportation failure depends on where it was detected. Table 11 shows how transportation feedback costs have been allocated in observation period.

***Table 11** Allocation of transportation feedback costs.*

Transportation Feedback		
Total Cost	0,8 %	
Responsible Part	**Share**	**Assigned Cost**
LEG 3	1,00	0,8 %

As table 11 shows all transportation feedback costs are now allocated to leg 3. Reason for this is that transportation feedback costs are external failures detected by customer and that's why these failures are caused in last leg of delivery; otherwise they should be included in internal failures. Overall transportation feedback costs seems to be relatively low when we remember how complex that last leg is (see figure 20) and also operated by many different kind of logistic service providers.

All feedback costs are now allocated to responsible parts of delivery chain depending on actual reason for feedback. This is the main difference between new CoPQ model and current way to measure feedback costs. This new way to allocate feedback costs is more realistic and now also other functions, than only manufacturing, are responsible for feedback costs. Table 12 is summarizing all allocated feedback costs in percentage of total feedback costs.

***Table 12** Summary of allocated feedback costs.*

Feedback category			ORDER HANDLING	MILL	LEG 1	LEG 2	LEG 3	TOTAL %
Internal	Internal Faults	ZI			0,33 %	14,94 %	1,16 %	16,43 %
External	Product Faults	ZB		67,60 %				67,60 %
	Service Faults	ZC	2,35 %	3,45 %	3,11 %	3,11 %	3,11 %	15,13 %
	Transportation Faults	ZT					0,84 %	0,84 %
TOTAL %			2,35 %	71,05 %	3,44 %	18,05 %	5,11 %	100,00 %

Credited feedbacks (% of total CoPQ)	23,32 %
% of revenue	0,28 %

As summary is showing product feedbacks (68%) and more over external failure costs are generating most (84%) of the credited feedback costs, when only 16% are internal feedback costs. It's clear that still the mill is carrying the biggest portion of credited feedbacks, because product feedbacks are still assigned to mill. However in this model also notable is that logistic leg 2 is now collecting 18% of total feedback costs. After all, total feedback costs are still steady when compared to revenue of same market area, only 0,28 %. More important than total amount of feedback costs in this model, was especially a new way to allocate feedback costs more realistic way.

7.2 Cost structure model for delivery chain

Next three subchapters are concentrating on introducing poor quality activities arising from logistic operations and how these costs should allocate in CoPQ model. In this section, the cost structure model for delivery chain is created for finding out average costs for every activity and leg in logistic chain. Because cost structure should model all committed costs for deliveries from mill to customers and back to mill, the structure is also including the return logistic and value of re-pulped scrap. This cost model is collected from 2-year manufacturing-, logistic-, external converting and pulp compensation cost data, and it can be used for analyzing cost structure and cost accumulation in delivery chain. More over this model is used as an activity driver for allocating actual total CoPQ for each part in delivery chain. Second section is concentrating to allocate those actual costs by using created average cost structure and actual back to mill returned scrap volumes within one year observation period. Thus all committed costs can be seen as a CoPQ for those defected products returned back to mill. This means that originally value-added costs in delivery chain are actually turning in to poor quality costs when product is, for reason or another, returned back to mill and risks are materialized. Third part of these logistics costs is focusing on non-value-added logistic costs which are occurring in delivery chain and can be seen originally as a poor quality and assigned directly to sources.

Next, the cost structure model for delivery chain is created, and it’s still good to remind that this model will be used later for allocating actual poor quality costs, but can be used also for analyzing delivery chain through average costs per ton. Because manufacturing costs and logistics costs strongly depends on type of delivery and product, the cost structure model is divided in three parts: Make-to-order (MTO) sheets, make-to-order reels and make-to-stock (MTS). Shortly MTO means deliveries which are made for exact customer, so products are made to order and products have been sold before manufacturing. This means that after manufacturing products should be delivered to customer without storing them in stock for long times. MTS is opposite way to deliver products and it means that products are made to stock and sold from there. Delivery type doesn’t really have affection to manufacturing costs, but usually logistic costs are lower for MTS. This is because deliveries of MTS are more flexible and not that busy, when MTO deliveries are usually delivered as soon as possible. Also MTS deliveries are always delivered to near customers in reels and if needed then converted to sheets there, which makes logistic costs lower. Case company is delivering products in two forms reels and sheets, which is affecting the manufacturing costs, when sheets are more expensive to produce, because of sheeting operation. Also logistic costs are higher for sheet, because they are more difficult to handle and need extra care.

These three different scenarios will be introduced closer in following subchapters. All costs in this cost structure model are collected from actual 2-year data, excluding some filtered error values. Also all non-value-added activities are filtered away from this model, because idea is to figure out value-added activity costs, when those costs of non-value added activities are later assigned directly to their sources. Basically these value-added activities included to this cost structure model are:

- Manufacturing
- Transportation (road, rail, sea)
- Handling (domestic, foreign, loading)

- Port fees
- External converting
- Re-pulping

All these cost structures are also illustrated in appendix 2 and 3, with more visualized figure version. Appendix 2 includes cost structures of delivery chain from mill to customers in each three scenarios, MTO sheets, MTO reels and MTS. Appendix 3 includes return delivery chain from customer back to mill for sheet and reel scrap.

7.2.1 Make-to-order delivered sheet products

First scenario in the model is concentrating on MTO delivered sheet products. This means, all products have been first manufactured at Äänekoski mill (BAKI) and then also sheeted at the mill. After that the sheets are delivered to customers through Hanko (HKO) to Antwerp (BEAN) or Lübeck (DELS), and then directly delivered to customer or sometimes through distribution centers (DC) to customers (CS). Table 13 is illustrating all costs in leg-by-leg basis all the way from the mill to the customer and back to the mill for re-pulping. All costs are expressed in percentages of total CoPQ. Because there are three possible routes for these deliveries, the cost accumulations for these are also collected to figure 22.

Table 13 *Cost structure for make-to-order delivered sheet products.*

Total cost of delivery chain											
MTO/SHEETS		Arriving Point							Cumulation		
Activity	Departure Point	BAKI	HKO	BEAN	DELS	DC	CS	PULP	BEAN without DC	DELS without DC	DELS with DC
Manufacturing	BAKI	98 %							98 %	98 %	98 %
Logistics 1	BAKI		3 %						101 %	101 %	101 %
Logistics 2	HKO			8 %	7 %				109 %	108 %	108 %
Logistics 3	BEAN						4 %		113 %		
	DELS					5 %	6 %			114 %	113 %
	DC						2 %				115 %
Return 1	CS			4 %	6 %				118 %	120 %	121 %
Return 2	BEAN		5 %						123 %		
	DELS		4 %							124 %	125 %
Return 3	HKO	6 %							129 %	130 %	131 %
Re-pulp	PULP							-31 %	98 %	99 %	100 %
TOTAL COST €/Ton		68 %	76 %	89 %	87 %	98 %	100 %	0 %	98 %	99 %	100 %

Because products are sheeted already at the mill, manufacturing costs are higher than in reel products. From Äänekoski mill to Hanko sheet products are delivered via road transportation, because from the sheeting lines there's no direct connection to the railway network. This makes logistic cost for leg 1 a bit higher than it is for reels, which are transported via rail. From Hanko to Antwerp or Lübeck all deliveries, including MTO or MTS in reels or sheets, are moving via sea transportation. Again sheets are generating a bit higher costs than reels, what is caused by higher transportation and handling costs. Port fees are naturally the same for all deliveries. After discharging ports in leg 1, sheets are delivered to customers directly or through distribution centers, operated by external actors.

Notable in deliveries of sheet products is that there are no external converters included, because sheets are already converted at the mill, in Äänekoski. Return logistic costs seems to follow same trend that they are higher than for reel products. Especially high return costs are in the leg from the Port of Hanko to the mill. This is probably because delivery volumes for that route are not high and that’s why price is also higher. In contrast, because of low volumes, return costs for leg 2 are relatively low, which can be explained with different operation logic of sea transportation. Worth to mentions about return costs is that cost of returns from customers to discharging port is not available. That’s why for return costs from CS to DELS and CS to BEAN are estimated to be same as delivery costs from ports to customers. These costs should be close enough to realistic costs, because the returned products are carried via same route and by same logistics operators as the products have been delivered to customers.

The value of re-pulped scrap is showed as negative value in table 13, because scrap is used again as a raw material in manufacturing process by re-pulping it. Thus this re-pulped scrap can be valued same as current price of mechanical pulp. This is the reason, why in this model re-pulping is lowering the costs.

On the left side of figure 22, we can see how costs of make-to-order delivered sheet products are accumulating through delivery chain in percentage of total CoPQ. As expected, manufacturing costs are generating the biggest share of total costs. After manufacturing costs are cumulating steadily and any huge leap between different stages can’t be found from this figure. Delivery costs through Lübeck seem to be slightly lower than Antwerp, because of shorter distance. However, costs for whole delivery chain seem to be lower through Antwerp, because of lower costs in leg 3.

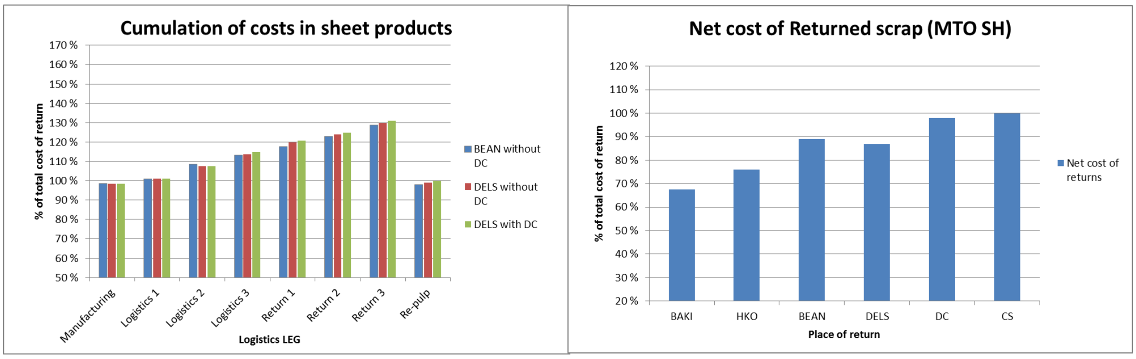

Figure 22 *Cost accumulation (on left) and net cost of returned scrap (on right) for three possible routes of MTO delivered sheets.*

On the right side of the figure, net costs of back to mill returned sheet scrap are illustrated. Costs are expressed as a percentage and compared to the highest costs, which is the costs of return from customer, so the costs of returned from customer is 100%. This figure is summarizing all costs and pulp compensation for returns, so it's shows how much it costs if one ton of scrap in sheets is carried back to mill and used again in manufacturing process. Again it seems that costs of returns from Lübeck are slightly lower than Antwerp, because of shorter distance.

The significant role of compensation from re-pulped scrap can be seen in last part of delivery chain (left graph in figure 22). However, the value recovered from re-pulp seems to cover only logistic costs to customer and back. As a conclusion, every ton of scrap returned all the way from customer back to mill and re-pulped means wasting amount of all manufacturing costs, when re-pulp compensate logistics costs. Respectively net cost of scrap detected and re-pulped directly at mill is less than 70% of cost of scrap returned from customer (right graph in figure 22). These figures can be later use for analyzing the cost structure of CoPQ in cartonboard deliveries and making decisions between returns and other options.

7.2.2 Make-to-order delivered reel products

The second scenario also illustrates MTO deliveries, but this time products are in the form of reels, which makes some differences in costs and routes. Reel products can be sold to customers as reels or just carried closer to the customer and sheeted there. In any case, these reels are sold already before manufacturing, like it was also in the previous scenario. The delivery chain is basically similar as in the previous scenario, but now external converter in Winschoten (ZWIN) is included for sheeting, re-winding etc. extra operations. Table 14 is illustrating cost structure of MTO delivered reels.

Table 14 *Cost structure for make-to-order delivered reel products.*

Total cost of delivery chain													
MTO/REELS		Arriving Point								Cumulation			
Activity	Departure Point	BAKI	HKO	BEAN	DELS	ZWIN	DC	CS	PULP	BEAN without DC	BEAN with converting	DELS without DC	DELS with DC
Manufacturing	BAKI	103 %								103 %	103 %	103 %	103 %
Logistics 1	BAKI		3 %							106 %	106 %	106 %	106 %
Logistics 2	HKO			9 %	7 %					115 %	115 %	113 %	113 %
Logistics converting (IN)	BEAN					4 %					119 %		
Converting	ZWIN					18 %					137 %		
Logistics converting (OUT)	ZWIN							12 %			149 %		
Logistics 3	BEAN							5 %		120 %			
	DELS						7 %	6 %				119 %	120 %
	DC							3 %					123 %
Return 1	CS			5 %	6 %					127 %	156 %	125 %	129 %
Return 2	BEAN		4 %										
	DELS		6 %							132 %	161 %	131 %	135 %
Return 3	HKO	6 %								138 %	167 %	137 %	140 %
Re-pulp	PULP								-40 %	98 %	126 %	96 %	100 %
TOTAL COST €/Ton		63 %	71 %	84 %	84 %	114 %	97 %	96 %		98 %	126 %	96 %	100 %

As mentioned earlier, usually costs for reel products are lower than for sheets. Because reels are not sheeted at mill, manufacturing cost is lower by excluding sheeting operation cost. Unlike sheet products, reels can be loaded directly from production line to trains and transported via rail to Hanko. This can be seen as lower transportation costs in leg 1, but also lower handling costs in leg 2. Overall reels are easier to transport and handle, what of course means lower logistics costs. As earlier scenario, also for reels there are several possible routes, which are cumulating costs different ways. These different routes and accumulation of costs are illustrated on the left side of figure 23.

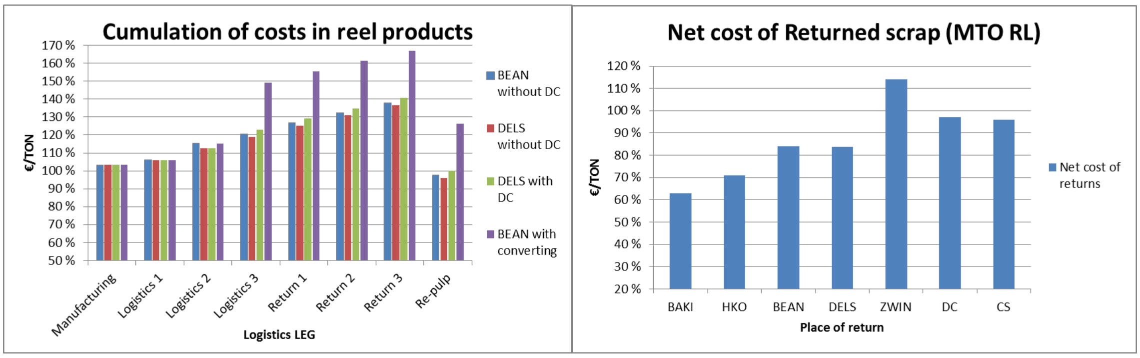

Figure 23 *Cost accumulation (on left) and net cost of returned scrap (on right) for four possible routes of MTO delivered reels.*

For reel products there are same three possible routes for deliveries as it was for sheets too. For reels there is now also one additional route which is going through external converting in Winschoten. As we can see costs are cumulating similar way as it was in case of sheets, steadily after manufacturing. However costs are overall lower in reels than sheets, what can be explained with lower manufacturing and logistics costs. The costs of converting can be seen as a big leap in leg 3. This leap can be compared to sheet products which were converted, sheeted, already at mill and delivered through BEAN without DC. There is only small difference between these two options, and seems that converting at mill is slightly cheaper. However, for making any further decisions between these two options managers should consider the overall situation, not only costs. Also converting operations are still different at mill and in Winschoten, what makes comparing these two even more complex. When comparing these costs we need to take also other business factors into consideration. For example in this case, we also should remember benefits of late customization which helps to respond faster to changing demands. Also, by using external converting near the customer, committed costs can be delayed and so lowering risks.

On the right side of figure 23, net costs of returned scrap are illustrated by place of return, as it was also did in case of sheets. Overall, these costs seem to be lower than it was with sheet products, which is mostly explained with lower manufacturing and logistics costs. However external converting in Winschoten is making a big leap in costs, this is because of converting costs and additional logistics. Returns from customer or distribution centers seem to be lower than it is from external converting. This is only true when returned products haven't been converted to sheets. So, if returned scrap is converted, of course, also converting costs should be considered.

7.2.3 Make-to-stock deliveries

Third, and last, scenario in this cost structure model is MTS delivery type. In this delivery type, there's no need for separate sheets and reels, when MTS deliveries are always carried in reels until external converting and from converting to customer in sheets. This is why manufacturing costs are same as reels. In table 15 cost structure in leg-by-leg basis is illustrated, similarly as in previous scenarios also. Now new parts in delivery chain are two external converters in Gohrsmühle (ZGOH) and Winschoten (ZWIN). This means there are basically two different route options to deliver these MTS deliveries, through ZGOH or through ZWIN. Deliveries through ZGOH are shipped from Hanko to Antwerp, and deliveries through ZWIN are shipped from Hanko to Lübeck.

Table 15 *Cost structure for make-to-stock delivered products.*

Total cost of delivery chain											
MTS		Arriving Point								Cumulation	
Activity	Departure Point	BAKI	HKO	BEAN	DELS	ZGOH	ZWIN	CS	PULP	Converting in ZGOH	Converting in ZWIN
Manufacturing	BAKI	81 %								81 %	81 %
Logistics 1	BAKI		2 %							83 %	83 %
Logistics 2	HKO			7 %	5 %					89 %	88 %
Logistics converting (IN)	BEAN					2 %				91 %	
	DELS						2 %				90 %
Converting	ZGOH					21 %				112 %	
	ZWIN						14 %				104 %
Logistics converting (OUT)	ZGOH							9 %		121 %	
	ZWIN							12 %			116 %
Logistics 3	BEAN										
	DELS										
	DC										
Return 1	CS			5 %	6 %					125 %	122 %
Return 2	BEAN		5 %							131 %	
	DELS		4 %								126 %
Return 3	HKO	5 %								136 %	132 %
Re-pulp	PULP								-32 %	104 %	100 %
TOTAL COST €/Ton		49 %	56 %	69 %	65 %	98 %	85 %	100 %		104 %	100 %

As we can see all costs are overall lower than previous scenarios, which is mainly because these deliveries are made to stock deliveries. This means, deliveries can be manufactured and carried to those stocks in advance and with lower priority, what means lower costs. However, MTS deliveries always include risks of over or under production, when production is based on forecasts. On the other hand, in MTS deliveries committed costs can be delayed to further, close to customer demand, when biggest leap after manufacturing costs is happening in converting, in leg 3. This accumulation of costs in MTS deliveries is illustrated on the left side of figure 24.

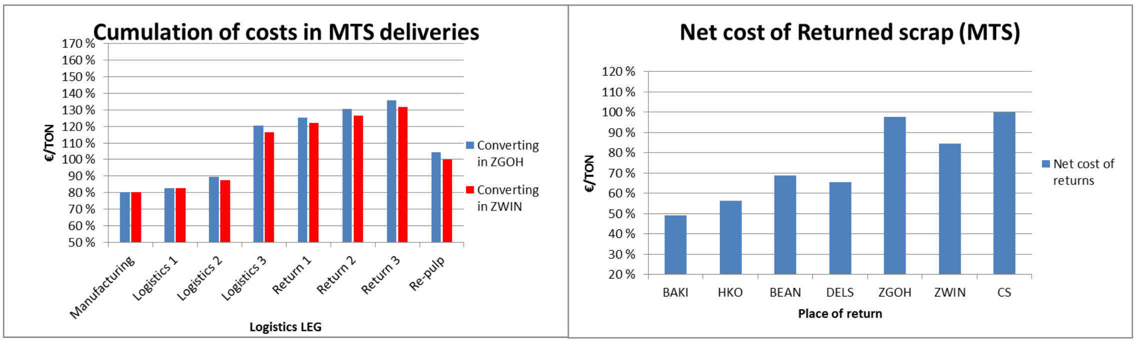

Figure 24 *Cost accumulation (on left) and net cost returned scrap (on right) for MTS deliveries.*

For MTS there are two optional routes: through Gohrsmühle or Winschoten. In figure 24 we can see that costs are cumulating mostly in late part of delivery chain, because sheeting operation is now made in latest possible part of delivery chain. When comparing ZGOH and ZWIN, there's a slight difference between them which is arising from leg 2 and external converting in leg 3. Difference in leg 2 is that deliveries to ZGOH are going through BEAN which is more expensive than delivery through DELS to ZWIN.

When remembering that MTS delivered products are sheeted by external converters and sold as sheet products, we can now compare this cost structure to MTO sheet products, introduced earlier. There seems to be only slight differences, but still these costs can be used for analyzing these options. However, when comparing these costs we need to take also other business factors into consideration. For example, we should remember benefits of late customization which helps to respond faster to changing demands, in case of MTS. Also, by using external converting near customer, committed costs can be delayed and so lowering risks at the same time.

On the right side of figure 24 the net costs of returned scrap, which was originally MTS delivered, is illustrated. Similarly as the two earlier scenarios, sheets and reels, also now these net costs of back to mill returned scrap is telling the net costs for one ton of returned scrap, with re-pulp compensation, by place of return. From this figure we can see directly how much more it cost per ton to return products back to mill from the pipeline rather than directly from the mill, the difference is huge.

7.3 Allocating costs of returns

In this section we will use the cost model created and introduced previous subchapter for allocating actual costs of back to mill returned defective products. It is worth to remind that costs of returns are allocated to responsible parts of the delivery chain depending on activity drivers. Costs are allocated depending on how big volume in tons each part of delivery chain have been carried and moved defections forward, not for those who originally caused failure. Allocating costs in this way, we can see how much resources in each part have been wasted for poor quality, and so it is also supporting the principles of TQM. Thus each stage in delivery chain should be responsible of quality, even if the failure would have originally happened in earlier stages.

The starting point for allocating costs of returns to responsible parts is the cost structure model which provides us average costs for every activity and every leg of delivery chain. Before those average costs can be used for allocating costs to mill, leg 1, leg 2, leg 3 and external converting, we need to summarize the delivery costs and the returning costs. These costs are illustrated in table 16, which shows now average costs per ton in percentage of total cost of route for back to mill returned scrap. Total cost per ton in each route has been illustrated in percentage of the most expensive route, so it's easy to compare them. For leg 1, leg 2 and leg 3 this means delivery and return costs of that leg. The mill is responsible of manufacturing costs which have been wasted for a defective product, as well as mill is getting benefits from re-pulped scrap. External converting should of course carry costs of converting, but also logistic costs from port to converting and from converting to customer.

Table 16 *Tonnage costs of returns allocated to each responsible part of delivery chain.*

Cost of returns (% of total cost/ton)						
Delivery route	MILL	LEG 1	LEG 2	LEG 3	EXT CONV	TOTAL
MTO SHEET BEAN (without DC)	69,01 %	8,64 %	13,20 %	9,15 %		96,10 %
MTO SHEET DELS (without DC)	68,29 %	8,55 %	10,78 %	12,38 %		97,11 %
MTO SHEET DELS (with DC)	67,60 %	8,46 %	10,67 %	13,27 %		98,11 %
MTO REEL BEAN (without DC)	65,97 %	8,62 %	13,73 %	11,68 %		71,18 %
MTO REEL BEAN (with convert in ZWIN)	50,62 %	6,62 %	10,53 %	8,97 %	23,26 %	92,76 %
MTO REEL DELS (without DC)	65,41 %	8,55 %	13,08 %	12,96 %		71,79 %
MTO REEL DELS (with DC)	62,83 %	8,21 %	12,56 %	16,39 %		74,73 %
MTS Converting in ZGOH	46,96 %	6,92 %	11,86 %	8,32 %	25,95 %	100,00 %
MTS Converting in ZWIN	48,97 %	7,21 %	9,31 %	10,41 %	24,10 %	95,89 %

As we remember, there are two types of deliveries and forms of products, as well as a few possible routes for deliveries. For investigating real CoPQ for returned products, we need to use their own costs for each scenario. All possible scenarios and their costs are illustrated in table 16. These costs are average costs which realized as CoPQ of each scenario and each part of delivery chain when something goes wrong and product is returned back to mill. These average costs in euros per returned ton are used as activity driver in our CoPQ model for allocating CoPQ of returns. Table 17 is illustrating next piece in this allocation process, returned volumes.

Table 17 *Actual back to mill returned volumes 7/2014-7/2015.*

Delivery route	Invoiced tonnes
MTO SHEET BEAN (from CS without DC)	42,77
MTO SHEET DELS (from CS without DC)	16,59
MTO REEL DELS (from CS without DC)	33,10
MTS CONVERTING IN ZGOH	3,48
MTO REEL BEAN (from CS without DC)	7,62
MTO SHEET DELS (from CS with DC)	1,28
Total returns	104,84

Returned volumes are categorized depending on their delivery type, are they in form of sheets or reels and their specific route. It's important to divide these volumes as we saw that there are differences in costs of different deliveries. When we use activity driver from table 16 to multiply these actual returned tons from table 17 we can allocate costs of returns as they are materialized. Summary of these assigned costs of returns is illustrated in table 18.

Table 18 *Summary of total assigned costs of returns.*

TOTAL ASSIGNED COSTS OF RETURNED PRODUCTS						
	MILL	LEG 1	LEG 2	LEG 3	EXT CONV	TOTAL
VOLUME (TON)	104,84	104,84	104,84	104,84	3,48	104,84
COSTS (% of total CoPQ)	6,52 %	0,83 %	1,24 %	1,06 %	0,10 %	9,75 %

Notable in table 18 is that actually all returns have been returned from customers or somewhere in leg 3. This means that all possible costs are committed to these returns, total costs of these returns are 9,75% of total CoPQ after re-pulp compensation. This is basically the costs wasted for manufacturing and delivering products to customer and back to mill for re-pulping. As we can see from table 18, again the mill is collecting most of the costs, because manufacturing costs are generating the biggest proportion of total costs. Costs allocated to external converting are very low, and again there might be maybe reason for that. Of course it might be that external converting is operating in very high quality level and there aren't really returns in their products. They are operating close to customers and maybe their responsibility for quality is higher. However, we need to remember that external converting is operating in the last part of delivery chain and so in this model they are mostly responsible of their own products, and after them there's only short distance to customer.

7.4 Allocating non-value-added logistic costs

In previous two subchapters the cost structure of delivery chain have been modelled and used for allocating CoPQ arising from back to mill returns. As discussed earlier those costs were originally normal operating costs, but after failure and return back to the mill those operating costs turned to CoPQ. Those costs can be understood originally as value-added costs, since they are creating value for customer by manufacturing and delivering products to customer. In this subchapter we will allocate those costs of logistic activities we filtered away earlier, when allocating costs of returns. These activities can be understood as non-value-added activities, since they are not creating value for customer and customer is not pay for it. Following non-value-added activities were occurring in this research observation period of 7/2014-7/2015:

- Unexpected costs
- Extra handling & cleaning & refurbishment
- Palettizing

- Transportation idle time for customer or warehouse
- Extra warehousing

These activities are clearly something which differs from normal "streamline" activities. Most common non-value-added activity is fixing or cleaning damaged product. Sometimes products might be even packaged again, if they are badly enough damaged. Even if this kind of activities are necessary in that situation and saving case company from bigger failure, after all customer is only paying for once packaged product. In this light all extra fixing, handling, packaging and cleaning are clearly causing CoPQ. Because the case company is using logistic service providers for all logistics activities, extra warehousing is also clearly counted as CoPQ. As explained earlier, service contracts with these service providers include warehousing costs until some day limit, and over that limit warehousing costs extra. Delivery chain of the case company is based on using these "free" periods of warehousing, and so extra warehousing is clearly CoPQ.

These non-value-added activities can be assigned directly to responsible parts of the delivery chain. This is because costs of these activities are originally registered for those locations where activities have been done. That's why actual total costs of these activities in observation period can be directly assigned. Table 19 summarizes assigned non-value-added logistics costs in percentages of total allocated cost.

***Table 19** Summary of allocated non-value-added logistic costs.*

Assigning Non-standard logistic costs						
Logistic cost type		LEG 1	LEG 2	LEG 3	EXT. CONV	TOTAL %
Handling Cost	H		20,23 %	6,27 %		26,50 %
Non-standard	N	2,13 %	40,54 %	3,68 %	0,16 %	46,52 %
Transportation	T	23,09 %		1,56 %	0,46 %	25,11 %
Warehousing Cost	W		2,20 %	0,29 %		2,50 %
TOTAL %		25,22 %	62,97 %	11,81 %	0,62 %	100,00 %

NVA Logistic Costs (% of total CoPQ)	3,64 %
% of revenue	0,04 %

Because these costs are logistic costs, it's clear that the mill is not collecting any of these costs. From table 19 we can see that leg 2 is collecting most of these costs, what is explained by sea transportation and port operations. In logistic cost types non-standard activities are causing most costs and actually extra warehousing costs are really low.

7.4.1 Direct deliveries

Even if absolutely most of the deliveries from Äänekoski mill are delivered via sea transportation, sometimes there are situations when direct deliveries from the mill to the customer are carried via road transportation. Reasons for direct deliveries are usually related to situations when delivery need to be fast or for some other reason delivery is decided to be better to delivered directly. Because this kind of activity is also differing from the normal standardized way to deliver products, it was expected to be one source of CoPQ. Costs of direct deliveries in observation period are illustrated in table 20 as percentage of average delivery costs.

***Table 20** Summarized costs of directs deliveries from mill to customer.*

Direct delivery from BAKI to Customer					
Departure Point	AANEKOSKI BOARD				
Arrival Point	CUSTOMERS				
	BE	CZ	DE	ES	Average
RL			60 %		60 %
SH	71 %	90 %	66 %	161 %	97 %

However, as we can see from table 20 these direct deliveries from mill to customer weren't actually more expensive than sea transportation. They were actually a cheaper way to deliver products to markets of Central Europe, except Southern France and Spain already became more expensive by direct delivery. This means that direct deliveries in this case should not be counted as CoPQ. Actually this issue with direct deliveries was also recognized in the case company, and came up in few interviews. Sometimes there have been even discussions about to increase volumes of direct deliveries, because it's cheaper and needs only two times handling per delivery. However increasing volumes is not really possible, due limited truck capacity and also negative affections to prices of sea transportation, because of decreased volumes via sea.

7.5 Waste & 2nd quality sales

For a reason or another, sometimes defective products are sold as a waste or second quality. This is of course not desired action because of lost profit and many risks included. However, it is happening sometimes and it should be understood as CoPQ since the company is losing its profit, especially in case of 2nd quality sales. Waste selling is normal action, when we talk about trim waste, from sheeting operations, but when it comes to defective products, it should be counted as poor quality. In this section we will discuss about this poor quality waste and 2nd quality sales and profit lost because of them.

When the product is returned to redundant stock from the customer or from another location, there are usually two options: return back to mill or sell product as a waste or 2nd quality. Costs caused because of returning products back to the mill was already discussed and allocated in chapter 7.3. Now we should also figure out CoPQ caused by waste and 2nd quality sales. Calculation of these costs, or lost profit, is based on sale numbers from same market area. With total sales and total invoiced volumes, average price can be figured out, and when same is done for waste and 2nd quality sales, the lost profit can be calculated as a difference of these prices. In table 21 sale numbers are illustrated for sheet-, reel- and all products in total sales, total invoiced volumes and average prices. Upper section in table is considering all sales, so it's also including waste and 2nd quality sales. This is real total sales, and so it can be also used later for other calculations. However for figuring out the lost profit, we should know average prices for prime quality, and that's why middle section of table is considering only prime priced sales. As we can see there's slight difference in these prices because of lower waste and 2nd quality selling prices.

Table 21 *Sales of observation period in focused market area for sheet and reel products as well as combined.*

ALL PRODUCTS	%	SHEET PRODUCTS	%	REEL PRODUCTS	%
Total Turnover	100,00 %	Turnover (% of all products)	82,53 %	Turnover (% of all products)	17,47 %
Total Inv Tonnes	100,00 %	Inv Tonnes	81,26 %	Inv Tonnes	18,74 %
Average price per Ton	100,00 %	Average price per Ton	101,56 %	Average price per Ton	93,23 %
Turnover of Prime Qlt	99,98 %	Turnover of Prime Qlt (% of sheets)	99,99 %	Turnover of Prime Qlt (% of reels)	99,90 %
Total Prime Tonnes	99,94 %	Prime Tonnes	99,98 %	Prime Tonnes	99,78 %
Average price per Ton (prime)	100,03 %	Average price per Ton (prime)	100,01 %	Average price per Ton (prime)	100,12 %
Turnover of Waste & 2nd Qlt	0,06 %	Turnover of Waste & 2nd Qlt	0,01 %	Turnover of Waste & 2nd Qlt	0,28 %
Waste & 2nd Qlt Tonnes	0,14 %	Waste & 2nd Qlt Tonnes	0,02 %	Waste & 2nd Qlt Tonnes	0,67 %
Average price per Ton (% of prime)	39,26 %	Average price per Ton	35,23 %	Average price per Ton	42,60 %
Loss Profit		Loss Profit		Loss Profit	
(% of prime price per ton)	60,75 %	(% of prime price per ton)	64,77 %	(% of prime price per ton)	57,45 %
(% of total profit)	0,30 %	(% of total profit)	0,04 %	(% of total profit)	1,33 %

The lower part of table 21 is summarizing waste and 2nd quality sales and lost profit because of them. Sale numbers and volumes of waste and 2nd quality have been filtered out from sale reports in ERP of case company. Good thing is that volumes sold with discounts seems to be very low, only 0,14% of total volume, but at the same time price of them seems to be also very low, only 39% of prime price. One reason for this can be poor reporting of discount sales, which means that actually some discount sales have been marked as prime sales. That's why we have to understand this error in statistic, and we can expect that actually discount price is not that low and on the other hand prime price should be a little bit higher. Also, when comparing these numbers with costs of back to mill returned products, we should remember labor costs related to selling and reorganizing process, as well as risks included to these discount sales. Risks related to lost reputation of company, distorted market prices and trademark piracy, should be always keep in mind when selling defected products in highly discount prices. When comparing these with cost of returns should also remember that usually returned products are not even suitable for selling, what means that original value of them have been much lower than discounted ones.

When allocating profit lost in waste and 2nd quality sales, it's difficult to say whose fault was that products has been sold in lower price or who should carry these losses. Generally we can understand these losses as a failure of delivery chain as a whole, and that's why every part of delivery chain should carry some of these losses. Table 22 is illustrating allocation of lost profit for all parts of delivery chain in percentages of total CoPQ.

Table 22 *Allocating lost profit for delivery chain.*

From Sales Report	
Turnover of Waste & 2nd Qlt	0,06 %
Waste & 2nd Qlt Tonnes	0,14 %
Average price per Ton (% of prime)	39,26 %
Loss Profit	
(% of prime price per ton)	60,75 %
(% of total profit)	0,30 %

Assigning lost profit of waste & 2nd quality sales		
Lost profit (% of total CoPQ)		**7,11 %**
Function	**Ratio**	**Assigned cost**
MILL	0,25	1,78 %
LEG 1	0,25	1,78 %
LEG 2	0,25	1,78 %
LEG 3	0,25	1,78 %
TOTAL	1	7,11 %

In table 22 we can see sale numbers for waste & 2nd quality in left side and allocated costs, or losses, in right side. Losses have been allocated equally for Mill, Leg 1, Leg 2 and Leg 3, because they all have caused waste and 2nd quality. However, since we don't have exact data of whose fault every single sale batch have been, it's a good estimation to share costs equally for every part.

7.6 External Converting

Earlier in cost structure model, external converting was discussed as a part of the delivery chain and how it's cumulating committed costs. Later that cost structure was used for allocating costs of returns to responsible parts of delivery chain. Now we should also figure out, how much external converters are wasting material because of poor quality and how much it cost?

As discussed before, external converters (within this case) are mostly doing sheeting operations, but also rewinding and ream wrapping. In sheeting operation reels are converted to sheets, that customer has ordered, so basically there can be as many sheet configuration as there are customers. This is of course good for customer service when products can be customized near customers with short lead times. However, when reels are sheeted there will be always more or less waste material. This wasted material which has formed as a left over in normal sheeting process is called as trim waste. The amount of trim waste depends on the sizes of reels and sheets, and right reel should be chosen for ordered sheet sizes in way that trim waste can be minimized. Because reels and sheets are changing all the time, the amount of trim waste is varying. For every single sheeting operation, external converters should try to minimize trim waste, but anyway it always exists in sheeting operations. Theoretically trim waste could be understood as a poor quality, if we could figure out theoretical minimum amount for trim waste and everything over that would be wasted because of poor quality. So, poor quality could be understood as a failure to minimize trim waste. However, measuring that in real life process would be much more complicated and not possible with current statistics, and after all maybe not even worth it. That's why trim waste, in this master thesis, is counted as normal operating waste, not waste because of poor quality.

Addition to trim waste, external converting is also causing waste because of failures in sheeting operation. This waste can be clearly counted as poor quality waste. This poor quality waste can be caused in external converting because of wrong sheet sizes, wrong amount of sheets or any kind of quality issue. Table 23 is summarizing allocation of CoPQ in external converting as percentages of total CoPQ.

***Table 23** Assigning CoPQ in external converting.*

Costs of external converting									
External Converting	Volumes (tons)	Waste (tons)	Waste (%)	Manufacturing costs (%)	Logistics costs (%)	Converting cost (%)	All costs committed (%)	Value of waste (% of committed costs)	Net cost of waste (% of committed costs)
Gohrsmühle	5 791,00	897,00	15 %	71,9 %	9,8 %	18,3 %	100,0 %	21,6 %	78,4 %
Winschoten	252,00	49,00	19 %	76,3 %	10,1 %	13,5 %	100,0 %	22,9 %	77,1 %

CoPQ in external converting					
External Converting	Waste (tons)	Waste because of Poor Quality (%)	Waste because of Poor Quality (tons)	Cost of Poor Quality (%/ton)	Cost of Poor Quality (% of total CoPQ)
Gohrsmühle	897	1 %	8,97	78,4 %	0,81 %
Winschoten	49	1 %	0,49	77,1 %	0,04 %
TOTAL	946	1 %	9,46	77,7 %	0,85 %

Because trim waste is not separated from other waste it's not possible to measure really accurately the amount of trim or poor quality waste. As we can see in table 23 all waste together is covering 15% in Gohrsmühle and 19% in Winschoten of total converted volume. Out of this total waste, approximately 1% can be estimated to be poor quality waste, and for this volume of waste we can calculate all committed costs. Committed costs are calculated by using costs structure of delivery chain, created earlier. By using the cost structure all committed costs, and so the real value of that waste can be calculated. Because waste is sold as a waste, of course that should be also compensated in costs.

7.7 Non-value-added labor activities

Earlier we have modeled and allocated feedback costs, costs of back to mill returns, costs of non-value-added logistic activities, lost profit of waste & 2nd quality sales and faults of external converters. However, all these poor quality activities are using also labor resources, which we haven't considered or allocated yet. In this section all those labor resources used for poor quality activities will be figured out, and costs generated by them will be allocated to cost objects.

Labor resources for poor quality activities are mainly used in technical service, customer service and sales. These non-value-added labor activities contain handling and solving feedbacks and other notifications, re-routing logistics and selling waste & 2nd quality. For every non-value-added activity, we can estimate some proportion about how much they are using resources. For this we have used FTE (Full Time Equivalent) ratio, which is basically telling, how many full time personnel's work contributions are used for this activity. Example FTE ratio 1,0 is telling that activity is using resources of one full time personnel, when 1,5 is using resources of one full time personnel and one half-time. Thus FTE is illustrating the actual work contribution used for some activity. Table 24 is showing these FTE ratios and labor costs for every task in various functions. As we can see, the FTE ratios are lower than number of personnel, because most of employees are using only some part of their full time for handling these poor quality activities.

Table 24 *Non-value-added labor resources (in FTE) and costs (per FTE).*

Function	Task	Number of personnel	FTE (all)	FTE (BAKI)	Labor cost per FTE (€)	Labor cost (% of total labor cost)
Technical Service	Technical support at field	11,9	7,14	2,3562	xx,xx	52,8 %
	Technical claim handler at mill	1	0,8	0,8	xx,xx	11,3 %
	Product Manager	1	0,05	0,05	xx,xx	0,7 %
	Technical marketing coordinator	1	0,05	0,05	xx,xx	0,7 %
Total		14,9	8,04	3,2562	xx,xx	65,5 %
Customer Service	Customer service cooordinator					
	Brussel	2	0,5	0,165	xx,xx	3,1 %
	Frankfurt	2	0,5	0,165	xx,xx	2,8 %
Total		4	1	0,33	xx,xx	5,8 %
Logistics	Logistics coordinator					
	Antwerp	1	0,2	0,066	xx,xx	1,2 %
		1	0,5	0,165	xx,xx	3,1 %
	Lübeck	1	0,5	0,165	xx,xx	2,7 %
	Return logistic coordinator	1	0,05	0,0165	xx,xx	0,2 %
Total		4	1,25	0,4125	xx,xx	7,2 %
Waste sales	Waste & 2nd quality sale	1	0,05	0,0165	xx,xx	0,2 %
Total		1	0,05	0,0165	xx,xx	0,2 %
Planning	Quality planners at mill	5	1,5	1,5	xx,xx	21,2 %
Total		5	1,5	1,5	xx,xx	21,2 %
TOTAL		28,9	11,84	5,5152	xx,xx	100,0 %

When FTE ratios have been estimated for every department, the costs of non-value-added labor resources can be easily calculated by multiplying with average staff costs. Average staff costs have been calculated individually for every department from payroll reports and it includes salaries, as well as other expenses like travelling.

As we remember, all poor quality costs should be divided in internal or external failure costs, and so do costs of labor resources too. This allocation of internal and external failure costs have been made by using notification types (product, internal, service, transportation) and number of credited notifications. The allocated non-value-added labor costs are illustrated in table 25.

Table 25 *Summary of labor costs allocation.*

Assigning cost of labor resources used for non-value-added activities				
Activities		Workload (in FTE)	Average labor cost (€/FTE)	Total non-value-added labor cost
Internal	Handling internal faults (ZI)	0,92	xx,xx	16,8 %
External	Handling product faults (ZB)	2,34	xx,xx	42,4 %
	Handling Service faults (ZC)	1,22	xx,xx	22,1 %
	Handling Transportation faults (ZT)	1,04	xx,xx	18,8 %
TOTAL		5,52	xx,xx	100,0 %
			% of total CoPQ:	55,3 %

As we also divided failure costs in internal and external earlier, when assigning feedback costs, so we can also divide now. Internal faults are allocated to internal failure costs and the rest to external failure costs. From the number of notifications, the ratios can be calculated and by multiplying with FTE ratios, we can get new FTE ratio, which tells how big proportion of non-value added labor resources have been used for solving internal and external failures. As we can see in table 25 most of the costs are naturally caused by handling product quality feedbacks.

7.8 Lost opportunities and reputation

Lost opportunities and reputation can be seen as a consequence of poor quality. When customers receive poor quality products or services, the company might lose their reputation, and next time it's more difficult to sell to this same customer, or even worse, the customer switch to another supplier. Therefore, one way to estimate these lost opportunities is to calculate the profit lost because of poor quality. This is only one way to consider these costs, but in context of poor quality costs in deliveries, this is relevant way.

However, the balance of capacity and demand should take into account when estimating lost opportunities. This is interesting issue, when usually poor quality and lost opportunities can be seen as lost revenue or profit, but sometimes when capacity is a limiting factor, it's impossible to sell more. So, even if company's reputation is declining and customers are not satisfied, if demand is still higher than supply, the company is not losing revenue because of poor quality, but because lack of capacity. In that situation, it could be better to estimate revenue, which has been lost caused by lack of capacity, and consider possible new investments for expanding capacity. Currently in the case company there is a lack of capacity and sales department is selling everything they can get out from the mills. However in the beginning of 2016, a few months after this master thesis, there will be remarkable expansion of production capacity. This new capacity will change the market situation, in way that the role of sales is increasing, when there's more to sell. Thus in this master thesis, lost opportunities are estimated through lost profit caused by poor quality, and will be discussed closer in following subchapters.

7.8.1 Lost sales resources

Estimation of lost opportunities is divided in two parts: lost sales resources and lost reputation. Poor quality is affecting to customer's image of the company and because of poor quality the reputation of company is declining. When this happens, it takes some time and resources of salesmen to recovering the trust of customers again. These resources used for recovering reputation, can be seen as lost sale resources, which could have been used for selling more for this or another, maybe even new customer. Salesmen want and their mission is to sell, not explaining or making excuses because of poor quality. Of course it's many times difficult to make the line between normal sales activity and explaining bad reputation. Similarly, it's difficult to estimate how a big proportion of these lost resources actually could have been materialized to revenue. However with some educated guess, it's still possible to estimate the magnitude of these lost opportunities.

For this case study, the Vice President of Sales and two segment directors in EMEA market area were interviewed and estimations for lost sales resources were made after deep discussions. These lost sales resources were then used for estimating total lost profit because of lost reputation. All interviewees divided customers to current and new customers. With new customers, the consequences of poor quality are bigger and much more difficult to repair, since one mistake might ruin whole deal. Instead, with current customers usually poor quality and mistakes can be fixed without losing customer, because of high switching costs. Customers who have a long history with the case company also understand more and are willing to solve problems together. However, if same mistake happens again then situation is usually more critical. If the case company has lost reputation and customer has switched to competitor, it’s usually very difficult, maybe even impossible, to acquire that customer back.

Because of different customers and different kinds of poor quality issues, it was very difficult to even estimate the amount of lost sales resources for recovering reputation. However in observed time period, from July 2014 to July 2015, there haven’t been really big problems with products of Äänekoski mill in this market area, so the amount has to be relatively low. Estimations were varying from 5% to 10% of average resources lost in observation period because of poor quality. That’s why in this research we will use 7% as estimation for lost sales resources. This is estimation for those resources used for solving issues with poor quality, and which could have been used for selling.

7.8.2 Lost reputation

Because of lost reputation salesmen have to use their time and resources for recovering poor reputation. These resources and time, they could have used, at least in theory, for selling more for existing customers or acquire new customers. In previous subchapter we discussed and figured out the lost sale resources, which we will use now for estimating total lost revenue due lost reputation. Table 26 is illustrating estimated lost profit due lost reputation.

Table 26 *Summary of lost profit due lost reputation.*

Lost profit due lost reputation	
Total Revenue	100 %
Total Inv Tonnes	63 837,54
Sale resources used for recover lost reputation (% of total)	7 %
Lost sales (ton)	4 468,63
Lost profit (in % of total CoPQ)	62,44 %

Lost profit has been estimated by using rate of lost sales resources (7%) estimated by sales directors. From total sales revenue and volumes we can estimate, how much this 7% lost resources means in tons, revenue and profit. Thus lost opportunities due lost reputation can be estimated in lost profit. This is the potential extra profit, which could have been achieved without poor quality. These lost opportunities might first look surprisingly high, but actually they are more representing potential and opportunity for quality improvements. This is good to keep in mind, when analyzing and using these numbers for making decisions.

Overall interviews and recently launched customer satisfaction survey are indicating good reputation of the case company. However in interviews it also came up that reputation has been better earlier, and especially lead times and services are issues customers are commonly complaining. Product quality seems to be in high level and customers really value it highly, but too often they are frustrated with long lead times and if problems are not fixed fast. In addition to high quality products, case company should concentrate more on customers and how to provide better value to customers. Interviewees underlined that quality issues related to product should be catch up already at mill to avoid their accumulation. If something goes wrong then fast response and fixing the problem is very important. For this reason customer service should be very well organized and effective when something happens.

7.9 Summary of new CoPQ model in case company

Above, the CoPQ model for case company's cartonboard deliveries have been created and introduced. The model contains activity based cost assignment for observed poor quality activities and resources they are using. As we remember from figure 21 resources were allocated for proper poor quality activities and then these activity costs were allocated further to responsible cost objects. This CoPQ allocation procedure was following the two-dimensional ABC model introduced earlier by Tsai (1998). By following this procedure it was possible to allocate poor quality costs for activities and finally for responsible parts of delivery chain. When poor quality costs are allocated for their root reasons, it's possible to analyze them deeper and find targets for improvement. This is a totally new way, when we compare it to current quality cost measure used in the company, which is only concentrated on credited customer feedbacks and directly assigning them to responsible mill. New CoPQ model is also measuring costs much wider context, not only as credited customer feedbacks. This should develop better knowledge of quality costs and their sources in cartonboard deliveries for managers.

In chapter 4.1 different quality cost models were introduced and discussed. CoPQ model used in this master thesis is combining traditional PAF model, opportunity model and ABC model. PAF was mostly applied to categorize different poor quality activities to internal and external failure costs. Prevention and appraisal costs were left outside of this work, because those costs are mostly controlled by mills and not directly related to delivery chain after the mill. As we remember internal failures, in this research, were defined as failures detected before the customer, and externals detected after the customer. Internal and external failure costs observed in deliveries of case company are as follows:

Internal failure costs

- Internal Feedbacks
- Handling Faults

- Transportation Faults
- Warehousing Faults
- Non-standard logistic
- Faults in external converting
- Non-value-added labor activities

External failure costs

- Product Feedbacks
- Service Feedbacks
- Transportation Feedbacks
- Lost profit (waste & 2nd quality)
- Returns back to mill
- Non-value-added labor activities

Opportunity losses were applied for underline the leverage of CoPQ to lost opportunities, like lost profit. This was relatively small part of our model, but it's important to remind managers about these opportunities lost because of poor quality. Improving quality is not only improving performance and lowering costs of improved operation, it might also boost revenues, when salesmen can concentrate only selling, not making excuses for poor quality. This creates huge potential to boost quality improvements.

Opportunity losses

- Lost sales resources
- Lost reputation

For allocating all these poor quality costs right and fairly for those responsible parts, which actually has caused them, the ABC procedure was applied. Some costs were possible to allocate directly to their sources, like non-value-added logistic costs, but then example costs of back to mill returns were allocated based on activity levels. By combining PAF, lost opportunities and ABC models, our CoPQ is mostly following "Integrated CoQ-ABC framework" by Tsai (1998), which is completely illustrated in appendix 1. This framework is very comprehensive and it is covering, not only cost allocation, but also how all this should be connected to missions and objectives of organization.

The summary table of CoPQ model in cartonboard deliveries is illustrated in table 27, and complete version of summarized CoPQ model is illustrated in appendix 4. This table 27 is showing all assigned CoPQ for each part of delivery chain and also for each poor quality activities. Responsible departments, which were our cost objects in cost assignment, are showed in upper part of the table. Similarly all internal- and external failure costs as well as lost opportunities are shown in left side of the table. Poor quality activities are also broken down in specific poor quality activities, so that costs generated by each activity can be seen directly from this table. The center matrix of this summary table is basically illustrating all allocated costs of poor quality activities caused by each department. These costs are then summarized by poor quality activities in right side of the table, and by departments in lower part of the table. Also percentages of all summarized poor quality costs have been illustrated in table 27, what will be useful when analyzing proportions and relations of generated poor quality costs.

Table 27 *Summary table of CoPQ model.*

Cost of Poor Quality (% of total CoPQ)											
Poor Quality Activities		Responsible department									
		Order handling	Mill	Leg 1	Leg 2	Leg 3	External Converting	Technical & Customer Serv.	Sales	Total	
										%	%
Internal	Internal Feedbacks	-	-	0,08 %	3,48 %	0,27 %	-	-	-	3,83 %	1,44 %
	Handling Faults	-	-	-	0,74 %	0,23 %	-	-	-	0,96 %	0,36 %
	Transportation Faults	-	-	0,84 %	-	0,06 %	0,02 %	-	-	0,91 %	0,34 %
	Warehousing Faults	-	-	-	0,08 %	0,01 %	-	-	-	0,09 %	0,03 %
	Non-standard logistic	-	-	0,08 %	1,47 %	0,13 %	0,01 %	-	-	1,69 %	0,64 %
	Faults in external converting	-	-	-	-	-	0,85 %	-	-	0,85 %	0,32 %
	Non-value-added labor activities	-	-	-	-	-	-	9,27 %	-	9,27 %	3,48 %
	Total	**-**	**-**	**0,99 %**	**5,77 %**	**0,70 %**	**0,87 %**	**9,27 %**	**-**	**17,61 %**	**6,62 %**
External	Product Feedbacks	-	15,77 %	-	-	-	-	-	-	15,77 %	5,92 %
	Service Feedbacks	0,55 %	0,81 %	0,73 %	0,73 %	0,73 %	-	-	-	3,53 %	1,33 %
	Transportation Feedbacks	-	-	-	-	0,20 %	-	-	-	0,20 %	0,07 %
	Lost profit (waste & 2nd quality)	-	1,78 %	1,78 %	1,78 %	1,78 %	-	-	-	7,11 %	2,67 %
	Returns back to mill	-	6,52 %	0,83 %	1,24 %	-	0,10 %	-	-	9,75 %	3,66 %
	Non-value-added labor activities	-	-	-	-	-	-	46,04 %	-	46,04 %	17,29 %
	Total	**0,55 %**	**24,87 %**	**3,33 %**	**3,74 %**	**3,76 %**	**0,10 %**	**46,04 %**	**-**	**82,39 %**	**30,94 %**
Total CoPQ (without opportunity loss)		**0,55 %**	**24,87 %**	**4,33 %**	**9,51 %**	**4,46 %**	**0,97 %**	**55,31 %**	**-**	**100,00 %**	**37,56 %**

Lost Opportunities	Lost reputation	-	-	-	-	-	-	-	62,44 %		62,44 %
	Total	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**62,44 %**		**62,44 %**
Total		**0,21 %**	**9,34 %**	**1,63 %**	**3,57 %**	**1,68 %**	**0,36 %**	**20,77 %**	**62,44 %**		**100,00 %**

As we can see from the table the mill is only generating external failure costs, because in this research we limited to observe costs after the mill. Internal costs generated by the mill are preventive and appraisal costs which were outside of this thesis. However the missing internal failure costs tells that all failures caused by the mill, have been let go all the way until customer. This is mostly because quality issues are difficult or almost impossible to detect within logistic chain, because products are packaged. However, the fact that mill is causing 20% of all CoPQ, should be taken seriously when planning prevention and appraisal acts in manufacturing process at mill.

Another important observation is the significantly high poor quality costs of non-value-added labor activities, which are allocated to technical and customer service departments in this model. Even if these costs might be little speculative, due to estimations made in allocation, it's illustrating the leverage of poor quality deliveries to non-value-added labor activities. So, more mistakes and poor quality is occurring in our delivery operation, more labor activities will be needed to solve these situations.

When we look at the percentages of different poor quality activities, we can clearly see that external failures are generating most of the costs. This relation between internal and external failure costs seems to be close to 20/80 ratio. This is natural when external failures are usually much more expensive, due to credited customer feedback etc. However, this also might be a signal that there's need for improve internal quality assurance and responsibility in the delivery chain. The outcomes of this CoPQ model will be analyzed deeper in next chapter.

8. ANALYZING COPQ IN CARTONBOARD DELIVERIES

So far in this master thesis, we have taken a journey from mapping out the current situation and clarifying research problems and –questions, to measuring CoPQ in the case company based on the most relevant theoretical background. In this chapter the key outcomes of new CoPQ model will be introduced and analyzed closer. Analysis will be three dimensionally focused on: 1. analyzing the CoPQ in deliveries of the case company, 2. analyzing cost structure of deliveries and 3. what these two models together provide for managerial work.

8.1 CoPQ in deliveries of case company

In the previous chapter, the procedure of CoPQ model was introduced and discussed thoroughly and some of the main findings were already pointed out from the figures and tables. In this section the key outcomes of CoPQ model will be analyzed, and targets for improvement will be discussed.

In literature CoPQ was many times expressed as a proportion of revenue, and so it's natural to start our analysis from those ratios and point of view. Earlier in table 6 current poor quality cost measure was illustrated, and we discussed how the case company is measuring only credited feedback costs for indicating quality levels currently. Table 6 shows results when quality costs have been measured through current procedure, with the same constraints we have in the new CoPQ model. Thus costs in table 6 are comparable with results of new model in table 27 and in appendix 4. For comparing the current credited feedback cost measure and new CoPQ model to each other, some of the most interesting factors have been summarized in table 28. CoPQ model is illustrated in two separate ways, with and without lost opportunities. This is because amount of opportunity loss is so huge compared to internal and external failures, that without them it's easier to analyze those internal and external failures closer. Also, we need to remember that these lost opportunities are speculative and uncertain, since it is illustrating lost opportunities and so it differs from failure costs in nature of cost type.

In table 28 we can clearly see the difference between the current measure and the new CoPQ measure. Currently only credited feedback costs are measured and allocated directly to the mill, when new CoPQ model is measuring many other poor quality activities within internal- and external failures, as well as lost opportunities, and allocating costs by using ABC principles. This is an important reform of the measure system when managers want to extend their knowledge from narrow performance of the mill view to broader performance of deliveries view. Now it is possible to assign poor quality costs to their root causes in each part of delivery chain, not only for the mill. Cost allocation row in table 28, illustrate distribution of allocated costs to each cost object, and as we can see currently all costs are carried by the mill, when new CoPQ model is allocating costs also for other parts. Because costs are allocated with ABC, based on poor quality activities, it's now possible to see in which parts costs are caused and where's the potential for improve operations and reduce cost of poor quality.

***Table 28** Summarized comparison of current credited feedback cost measure and new CoPQ model.*

Comparison of current and new CoPQ model						
	Current measure for credited feedbacks		New CoPQ model		New CoPQ model (with opportunity loss)	
Type of Costs	Credited feedbacks		Internal failures External failures		Internal failures External failures Opportunity costs	
Allocation principle	Directly to mill		Activity Based Costing		Activity Based Costing	
Cost allocation	Mill	100 %	Order handling	0,5 %	Order handling	0,2 %
			Mill	24,9 %	Mill	9,3 %
			Leg 1	4,3 %	Leg 1	1,6 %
			Leg 2	9,5 %	Leg 2	3,6 %
			Leg 3	4,5 %	Leg 3	1,7 %
			External Converting	1,0 %	External Converting	0,4 %
			Technical & Customer Serv.	55,3 %	Technical & Customer Serv.	20,8 %
			Sales	0,0 %	Sales	62,4 %
% of revenue	0,23 %		1,21 %		3,22 %	

Table 28 shows total amounts of CoPQ, or credited feedbacks in the current measure. The clear difference can be seen between the current measure and the new CoPQ model. This is obvious when current measure is only considering credited feedback costs and new CoPQ model is considering all poor quality costs, like non-value-added labor costs. We can compare them easily by using "% of revenue"-ratio, like it was also done commonly in literature for CoQ. However comparing to those numbers suggested in literature is not relevant when those are talking about CoQ and we have only measured CoPQ. That's why our rates are much lower than in literature. Anyway, with the current measure poor quality costs seems to be 0,23% of revenue, and with new CoPQ model poor quality costs seems to increase already to 1,21% of revenue. Both of these rates are relatively low, even if they illustrate CoPQ only. If lost opportunities are also included to this new CoPQ model, rate is increasing to 3,22% of revenue, which is much higher than two earlier options. This is illustrating the leverage effect of CoPQ, when even small improvements in delivery operations might have large consequences to sales.

With the new CoPQ model a more comprehensive view to poor quality costs can be created, and more poor quality costs have been measured. Credited feedbacks, measured currently, are only the tip of the iceberg in poor quality costs, but new CoPQ model is also taking a look below the surface. Instead of only focusing on increased total poor quality costs and "% of revenue"-ratio, it's even more important to analyze distribution of CoPQ in internal- and external failures as well as lost opportunities. Figure 25 is illustrating distribution of CoPQ without (on left) and with opportunity loss (on right).

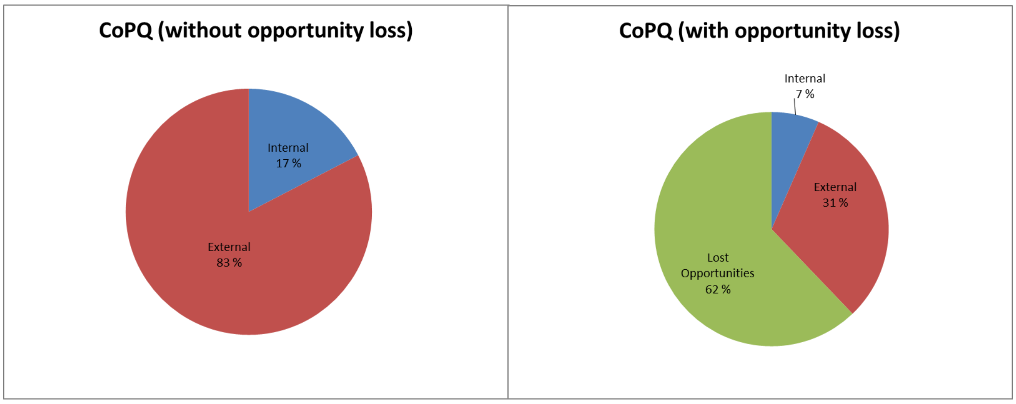

Figure 25 *Distribution of CoPQ without opportunity loss (on left), and with opportunity loss (on right).*

As we can see, internal failure costs are covering only a minor share of the pie. Internal failures are detected before the customer, internally in the company's own processes. That's why they usually cost less, because there's no need to credit anything for the customer. Also repairing internal failures are usually much easier and cost less than external failures, which have been detected by the customer. So, the reason why internal failures are taking only small piece of pie might be because they are usually cheaper to handle. However, a small share of internal failure costs might be also sign, there's need for improved internal processes, especially from quality point of view.

The pie chart on right side of figure 25 is also considering lost opportunities, and so the chart looks very different from the left one. Now we can see that opportunity losses are much bigger than failure costs by covering 62% of total CoPQ, when external failures are 31% and internals only 7%. This chart is telling the same story, discussed before, that lost opportunities are illustrating the true potential and leverage effect which CoPQ improvements have. So, when overall quality in deliveries is improved, more likely also lost opportunities are reduced and sales are improving. This is mostly because of improved quality salesmen can concentrate more on selling, and less on quality issues.

Dividing costs into internal- and external failures and lost opportunities, gave us good general level view to poor quality costs. For developing deeper knowledge of poor quality in deliveries of the case company, it's necessary to break down these costs even further than above. If we want to find the most potential targets for improvement, we need to understand the cost structure of delivery chain and how CoPQ is distributed by cost objects and by poor quality activities. The left chart in figure 26 is illustrating, which cost objects are generating CoPQ and how big proportion they are covering out of the total amount. Similarly, the chart on a right side of figure 26 is illustrating, which poor quality activities are generating CoPQ and how those costs are divided between activities. As discussed earlier, because of the different nature of lost opportunities, in this figure we only concentrate on failure costs. Thus, CoPQ in deliveries is easier to analyze.

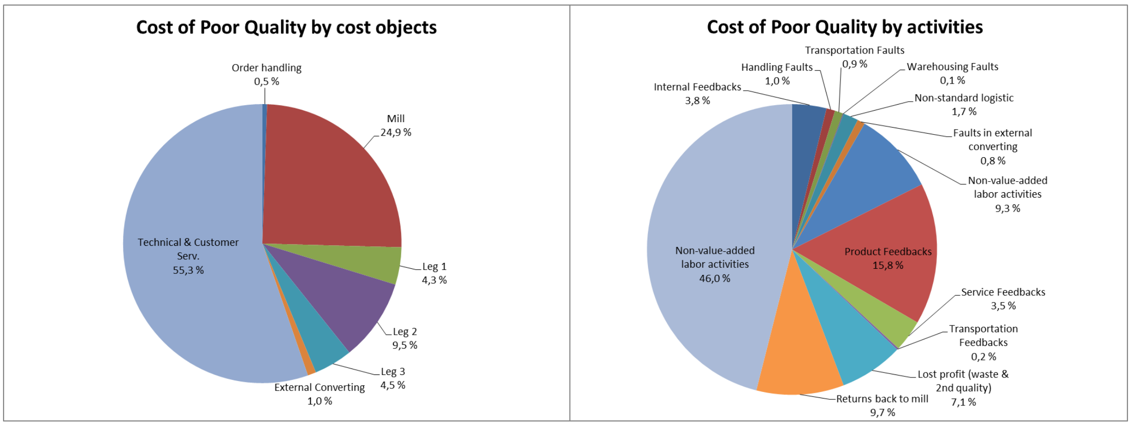

Figure 26 *Distribution of CoPQ by cost objects (on left) and by poor quality activities (on right)*

Because new CoPQ is using ABC for allocating costs of each poor quality activity for every responsible part of delivery chain, it's possible to take a deeper look to CoPQ and analyze root causes. The biggest share (55,3%) of CoPQ is generated in Technical & Customer Service because of non-value-added labor activities. Like we remember these non-value-added labor activities are used for handling customer feedbacks and solving problems caused by poor quality. This means, that more feedbacks because of poor quality, means naturally more non-value-added labor work in Technical & Customer Service. Poor quality is like a domino effect, if you don't stop it at as early stage as possible, it will affect all the other functions. That's exactly what happens for Technical & Customer Service, and also for sales in case of lost opportunities.

Even if new CoPQ model is allocating costs, not only for the mill, but for all other parts of the delivery chain, the share of the mill is still second biggest. So still the mill is actually the place, where the biggest opportunities for improvements can be found, after non-value-added labor activities. Another interesting point is that the share generated by mill is 24,9 %, but product feedback costs are only 15,8%. Thus, the mill is not only responsible for feedback costs related to product quality, but also costs caused by returns back to the mill and lost profit in discounted sales, as well as some part of service feedbacks. Those costs would have been avoided, if they could have been stopped originally at the mill. This is underlining the fact that mill is also responsible for the product after it leaves the mill.

As mentioned, poor quality is like a domino effect, and even if original reason for defection is caused by the mill, it should be stopped as soon as possible after the mill. That's why logistic leg 1, 2 and 3 are not only responsible of defections they cause, but also those they are forwarding. Figure 26 tells that logistics is generating 18,3% of total CoPQ which is a little over half of costs generated by the mill. Most of the CoPQ in logistics are caused in Leg 2, which is obvious when we remember that leg 2 is covering shipping from Hanko Port to Antwerp and Lübeck Ports. Thus leg 2 should be seen as a target for improvement in logistic operations. Leg 2 is generating around half of the all costs allocated to logistics, when leg 1 and 3 are sharing the another half.

Costs generated by order handling and external converting are very small, as we can see in figure 26. CoPQ generated by order handling is caused because of manufacturing or any other instructions have been wrong. Even if both of these parts of the delivery chain are generating a really small share of CoPQ, it's still important to include them into the model for creating a comprehensive view of deliveries. It's also important for understanding the consequence of poor quality in these parts.

Above we analyzed the information and results we have been able to collect with new CoPQ model. Now delivery chain and all operations related to it can be observed much closer and deeper than before. Thus new way of measuring CoPQ is giving much more relevant information needed for decision making process. Based on the analyzed information above few targets for improvement, or worth paying attention to, can be pointed out:

- External failure costs collect much higher share of CoPQ than internal failures.
- Remarkable big share of non-value-added labor costs.
- Relatively high share of poor quality costs allocated to mill.
- Poor quality costs of Leg 2 are double as high as in other logistic legs.

These are representing targets for improvement, since they are collecting the biggest shares of CoPQ. This list provides possible targets for managers to find those hot spots for developing their processes. However this lists is only meant to reveal and make visible those hot spots, but of course before improvements there's a need for deeper research of the target. These targets can be used as a starting point for continuous improvement process.

8.2 Cost structure of delivery chain

As we remember, in chapter 7.2 costs structure of the delivery chain was built for calculating the costs of back to mill returned scrap. Even if the model was mainly created for calculating and allocating costs of returns, this model can be also used for analyzing costs of the delivery chain. Further this model offers valuable knowledge of the delivery chain for managers. In this section the information provided by this cost structure model will be analyzed.

As mentioned, the cost structure was discussed closer in chapter 7.2 and cost structures of deliveries and return logistic are illustrated in appendix 2 & 3. Figure 27 is summarizing the cost structure of deliveries by illustrating the net costs of back to mill returned scrap.

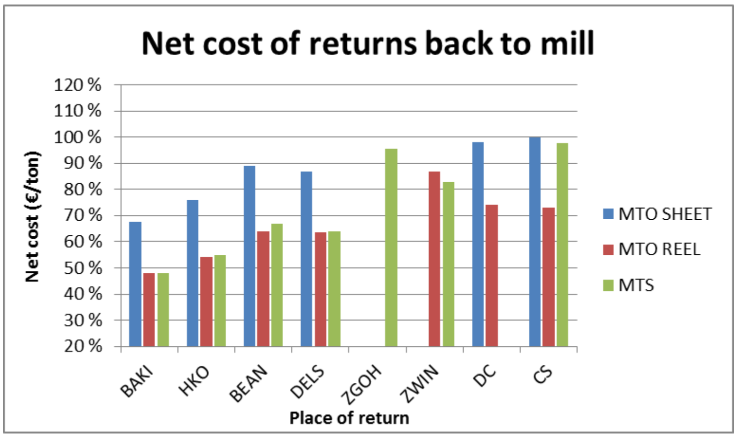

Figure 27 *Net costs accumulation of returned scrap by place of return, delivery type and product form.*

Now costs are illustrated in percentage of the highest value, which is the cost of sheet products returned from customer. Therefore cost structure is illustrated in way that reader can immediately see the cost of returned scrap by location scrap has been returned. Three main delivery types are collected to the same figure to making comparing easier. MTO delivered sheet products are naturally more expensive in early stages, because of sheeting operation at mill and because of more expensive logistics. Costs of MTO delivered reels are naturally the lowest because of missing sheeting operation and also lower logistics costs. MTS deliveries are generating costs more at late stages of delivery, because sheeting operation is done near the customers in very late stage of delivery. The figure is also telling directly how much it costs to return scrap back to the mill, when the value of re-pulp is considered. If the defected product is managed to catch directly at the mill it costs around 50% for reels and for sheets almost 70% compared what it cost when returned from customer. This means, if defects could be caught at the mill the case company could save around 30% of all costs in sheets and around 20%. And, if those defects could be completely avoided, then company could save even 50% in reels and almost 70% of all failure costs. This proves clearly the need and importance of preventive and appraisal actions and efforts, when failure costs are increasing rapidly after the mill. This should be communicated to factory level and all who are working in manufacturing process, especially quality inspectors.

Cost structure of deliveries is also providing information for comparing different kind of options, example decision between own sheeting and external converting near the customers, or between discount sales and return back to the mill. As we remember, products of the case company can be delivered as reels or sheets to the customer and they can be sheeted already at the mill or carried to stock near the customers and sheeted by an external converter. In figure 27 it seems to be almost same cost for both of these options after all. Only difference is that MTS products, which are sheeted near the customers, costs are cumulating in later stages, when MTO sheet, sheeting cost is committed already at the mill. For MTS products risks are lower, because of late accumulation of costs and because then products can be customized close to demand. But on the other hand, MTS deliveries are including warehousing costs and so also committing capital. However this cost data can be used for this kind of decision making and it is valuable information for managers.

Another decision making situation, which this cost structure can be used for, is decisions between discount sale and returns back to the mill. Comparing these two options is possible, when we know lost profit of discount sales and similarly costs for returns back to the mill. In this light returning seems to be only a little bit more expensive, but when we think closer and consider also the risks and labor work used for selling as a waste or 2nd quality, returning becomes a very desirable option. Therefore managers should ask themselves, how much they are ready to use effort and take risk for saving this little margin. These are only few examples of possible decision making scenarios, this model can be used. Next chapter is analyzing more contributions of CoPQ information for managerial work.

8.3 Contribution of CoPQ model into managerial work

What can this CoPQ model and new information, can offer for managers? And, how can, or should, this information be used in managerial work, and where all this is aiming for? These questions about the contribution of CoPQ model into managerial work will be discussed in this section. Figure 28 is illustrating the structure of CoPQ information, its sources and using, as well as few examples.

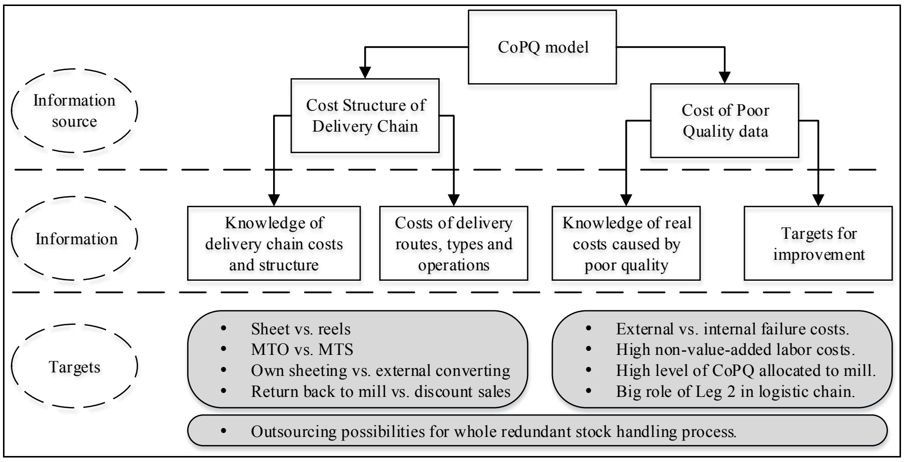

Figure 28 *Use of CoPQ information in managerial work.*

Figure 28 reminds us that even if CoPQ model is in the spotlight of this master thesis, we should not forget the cost structure of the delivery chain and information it provides. Both of these sources are providing a bit different kind of information and they are complementing each other. As information level shows both of these information sources are providing information for knowledge developing, but they can be also used for specific decision making scenarios.

Earlier CoPQ in cartonboard deliveries was analyzed based on measured CoPQ. Next analyzation is concentrating on, how to use this information in managerial work. As we remember from chapter 5.3, accounting information is primarily used for developing knowledge of business environment, but also for specific decision making scenarios. Next we will analyze new CoPQ model and information it offers, from these two different perspectives:

1. Developing knowledge of business environment.
2. Specific decision making scenarios.

Like we learned in chapter 5.2, using information for specific decisions is relatively small part of managerial work and more often information is used for developing knowledge of current situation and business environment. It is also true in case of CoPQ, since it can be used for some specific scenario, of course, but moreover CoPQ information is providing very comprehensive information for developing knowledge of delivery chain and its quality.

CoPQ data is providing knowledge of real costs caused by poor quality. This is remarkable, when we remember how narrow the point of view is that the current measure provides. This new CoPQ model is observing the delivery chain and especially quality costs in much wider way and so it is providing deep knowledge of poor quality and its costs in deliveries. With this information managers are able to understand, how much poor quality actually costs at the mill, at the port, at the customer or at any point of the delivery chain, and even further how much it costs to fix it. As we remember, the current quality cost measure was only considering product quality feedbacks, when the new CoPQ model is considering a much wider way all poor quality costs within the delivery chain. This should give a clear view to managers how poor quality is occurring in products, but also in operations, as well as consequences of poor quality. When managers understand the whole picture of quality costs, they can see new opportunities for improvements and it also motivates actions for improving quality.

A little bit different kind of information for managerial work is provided by cost structure model of deliveries. This information is maybe even more general level knowledge and helps managers to create clear view of the delivery chain and costs related to that. Different routes, types and operations are described and their costs are calculated, which gives a good view of the delivery chain in context of this research. It is worth to remind that the delivery chain of this thesis is covering deliveries from Äänekoski mill to Central Europe markets. Deliveries to other markets like North-America or APAC are significantly different and this cost delivery chain model should not be directly used for analyzing those delivery chains. However, when managers are able to expand their vision to the delivery chain they can see more options and opportunities there, and use that knowledge also in other context. This is a big benefit of this information, when it can be also applied elsewhere for wide range of decisions. Knowledge of the delivery chain and its cost structure is helping to find a solution for the new, continuously changing situations, and make better decisions fast. Further it develops manager's skills to prepare for the future situations in advance.

Based on developed knowledge of the business environment, specific decision making scenarios can be solved. Even if the new CoPQ model is not specified for only one or few decision making situations, it is still possible to recognize some of those situations when information provided by CoPQ model would be helpful. These kinds of scenarios were already introduced earlier in chapters 8.1 and 8.2, as well as in figure 28 boxes with grey background. In addition to these, information of the CoPQ model can be used also very well for make-or-buy decisions related to the delivery chain. One this kind of scenarios we already introduced when we talked about decision between sheeting at mill or using external converting. Another very interesting decision making scenario would be related to whether to outsource the whole redundant stock handling process for external service provider. This would basically mean, that always when defect is detected in the delivery chain or customer return defected product, external service provider would take and handle all that "negative flow", as we called it earlier in figure 16.

As it was underlined in the literature review, the importance of preventive and appraisal actions is undeniable. The primary goal of quality improvement should be concentration to prevent failures before they even exist. This research has concentrated on measuring failure costs, consequences of poor quality, and thus helping managers to justify and target investments to actual preventive and appraisal actions. Thus this research offers directly valuable information for decisions related to quality improvements.

As we have learnt the information this research provides, can be used many ways in managerial work. Developed knowledge can be used for everyday supply chain management, but also for specific decision making situations. Information of cost structure model can support to make decisions between different operational options in deliveries. After all the ultimate contribution to managerial work of this research is to kick-start a continuous quality improvement process by helping to justify and target preventive and appraisal actions.

9. CONCLUSION AND FUTURE RESEARCH

This final chapter will conclude the research and propose possible future research opportunities based on this work. First main outcomes and how this research met objectives will be summarized. Then contribution of this research for both, managerial and academic work will be discussed. After that research validity, reliability and relevance will be evaluated, and future research opportunities proposed.

9.1 The main outcomes

The aim of this case study was to open manager's eyes for poor quality by investigating and measuring CoPQ in a more realistic and holistic way. With this broader view and deeper knowledge of poor quality managers should be able to make better decisions. The purpose of the research was captured in four research questions, which will be answered and discussed next.

How poor quality occurs in cartonboard deliveries of case company?

The delivery chain from Äänekoski mill to the customers in Central European markets, as well as redundant stock handling and return delivery process was modelled, and all non-value-added activities were observed. These poor quality activities were then categorized in internal and external failures, and caused costs were allocated to their root causes, cost objects. As a result we were able to analyze, what kind of poor quality activities occurs in deliveries of the case company in each separate part of the delivery chain and how much they costs.

Internal failure costs are caused by defects detected internally before transferring ownership to the customer. However, defects related to product quality seem to be very hard to catch and stop between the mill and the customer. All internal failure costs are caused because of a failure in logistic operations or external converting, not because of product quality. This is underlining the importance of quality assurance at the mill, because next who is inspecting the product is usually the customer. Most of the internal failure costs seem to arise from logistic leg 2, which covers shipping operations, and non-value-added labor work in technical & customer service caused by all internal feedbacks. Thus even relatively small failures in deliveries are resonating to technical &customer service department as extra labor work, and so these failure costs are expanding.

External failure costs are caused by defects detected by the customer, and so they are more expensive and harmful for the company. Most of these failure costs are caused by credited product feedbacks, and non-value-added labor activities used for handling these feedbacks. Addition to this, poor quality activities caused because of returning and re-selling defected products are also included to external failures. Thus, new CoPQ model consider all activities which have been made because of poor quality.

Most of the poor quality activities in the delivery chain are external, and overall most of the CoPQ are generated by non-value-added labor activities. As mentioned, if defected products are not caught directly at the mill, it is very difficult in later stages of the delivery chain. It's obvious that the further defected products go or later defects happen, the more expensive they are, because of accumulated costs in the delivery chain. Poor quality in deliveries is similar as domino blocks, if you don't stop failures as soon as possible they are just increasing in the delivery chain and finally causing extra costs in many ways.

How much are the real costs of poor quality?

Total CoPQ in deliveries of case company measured with current measure were 0,23% of revenue, when only feedback costs were measured and assigned directly to mill. With new CoPQ model poor quality costs are 1,21% of revenue without opportunity losses and with opportunity losses the rate is 3,22% of revenue. Thus real poor quality costs are 5 to 14 times currently measured CoPQ. This difference is huge and underlines the fact that currently measured feedback costs are only the tip of iceberg. These much higher costs illustrate the importance and possibilities of CoPQ, but actually not much more. Therefore, for deeper and more fruitful analysis these costs should break down in cost of poor quality activities and cost objects.

Allocating costs of resources used for all poor quality activities and further to responsible parts, two-dimensional model of ABC (see figure 9) was applied. This makes possible to analyze poor quality costs by activities and by cost objects (see appendix 4), and find targets for improvement.

It was found that 83% of CoPQ was external failure costs and rest 17 % internal failure costs, when lost opportunities are not included. The reason for this might be the lack of internal quality inspection between the mill and the customer, but also because these failures have been delivered all the way to customer and so they are more expensive in nature. However relatively low internal failure costs is a sign that logistics operations are working at a relatively good quality level, especially when external transportation feedbacks are also low. If lost opportunities are also considered, then they are covering 62%, external 31% and internal failure cost only 7% of total CoPQ. This tells own story of the leverage effect poor quality has in cost of lost opportunities. Even if CoPQ in deliveries are not remarkably high, cost of lost opportunities because of CoPQ reveals the real potential for improvements.

When CoPQ is analyzed in activity and cost object level, targets for improvement can be pointed out as a high costs. First thing to pop up from the CoPQ model is the significantly high share of non-value-added labor activity costs in technical & customer service. This is because all poor quality activities in delivery chain are causing extra work for technical & customer service. Second interesting point is the 24,9% high share of the mill, even if product feedback costs are only generating 15,8%. This shows that only little over half of poor quality costs allocated to the mill are now because of product quality, and now also service feedbacks, discount sales and back to the mill returns are considered. This also proves that the mill is still potential target for improvement, since it generates second biggest share of CoPQ. Similarly in logistics chain the biggest opportunity for improvements is targeting to leg 2, which includes shipping operations. Poor quality costs allocated to leg 2 are double as high as it is in other logistic legs.

As we see, new CoPQ model provides much relevant and detailed information, and therefore offers much complete and comprehensive view of poor quality to managers. Some examples of targets for improvement can be summarized as we did also in chapter 8.1:

- External failure costs collect much higher share of CoPQ than internal failures.
- Remarkable big share of non-value-added labor costs.
- Relatively high share of poor quality costs allocated to mill.
- Poor quality costs of Leg 2 are double high as other logistics legs.

How poor quality affects satisfaction of customers, and what it means for business?

Consequences of poor quality highly depend on customer and magnitude of poor quality. With new customers consequences are usually more critical than with old customers, whose switching costs are high. However if the defect is big or it repeats many times, it will always have an effect on the customers satisfaction. In this research poor quality affecting the customer satisfaction was observed through sales resources and lost profit because of poor quality. In observation period it was estimated that salesmen are using around 7% of their time for handling poor quality issues with customer, instead of selling more. As a result the case company has lost, at least in theory, 7% of its profit because of poor quality and lost reputation. Even if this cost of lost reputation is speculative, because of estimations, it still gives idea of the magnitude and leverage effect of poor quality.

Based on interviews and recently launched customer satisfaction survey, overall it seems that the case company still has relatively good reputation, although it has been better before. Especially product quality is high, even if in this research product quality feedback costs were relatively high, which might be also because the customers really care and put high value for product quality. Lead times are usually common negative issue for customers of the case company, and that's maybe something which should improve, even if it's mostly because of mills are located far from the markets. Another concern which customers feel unsatisfied is the resolution time spent for fixing problems and helping the customer. This can be also seen clearly in this research, when non-value-added labor costs in technical & customer service are significantly high. Except slow resolution time is making the customer unsatisfied, it's also costs for the case company.

As a summary CoPQ can be seen as a domino blocks, where committed costs are just increasing through the delivery chain and affecting more and more costs and problems. Sooner or later these costs will be falling down to the case company anyway. Thus it should be primary importance try to prevent or catch defects as soon as possible, preferably directly at the mill. If some defects are entered to the delivery chain, there should be a way to inspect and catch defected products also during the delivery. To minimize effect on the customer satisfaction and costs of non-value-added labor activities, feedback handling process should be organized better and more effective for fixing situation as fast as possible.

9.2 Managerial contribution

At least as interesting as results of CoPQ model was above, is the use of this CoPQ information in managerial work. Fourth research question was related to managerial contribution and that's why it will be answered in this section.

What contribution CoPQ information can offer for managerial work?

It's obvious that current way to measure poor quality costs is way too narrow, and doesn't provide enough relevant and detailed information for supporting managerial work. Accounting information should primarily support managers to develop their knowledge of business environment and secondly used as an input into specific decision making scenarios. New CoPQ model can serve managers by providing relevant information for both purposes.

New CoPQ model is considering all poor quality activities, not only credited customer feedbacks, and then costs are allocated to root reasons. This makes the currently hidden poor quality costs visible, and explains where and why these costs occur in deliveries. When this information is used with cost structure model of the deliveries, created for cost allocation, managers are able to understand causal relationships and influencing factors in the delivery chain. Through knowledge development managers can see more possibilities and options in managing the delivery chain. This gives managers ability to react faster in on-going situations and prepare for the future, when they know what is really happening.

Because new CoPQ model is allocating costs to their root causes by activities and by cost objects, it is possible to find those hot spots, or targets for improvement. These clear targets help managers directly focus to right things. These targets for improvement were listed already in previous subchapter 9.1. For more specific decision scenarios, cost structure model of deliveries can be used for comparing costs of different options, when managing delivery chain. These specific scenarios could be example related to following issues:

- Delivery in reels vs. sheets.
- Delivery by MTO vs. MTS.
- Own sheeting at mill vs. external converting near markets.
- Return defected products back to mill vs. sell them with discount.
- Outsourcing whole redundant stock handling and return delivery process for external service provider.

These are only few examples, how CoPQ information can be directly applied to decision making process. How CoPQ model should built and implemented for managing delivery chain is illustrated as a continuous process in figure 29.

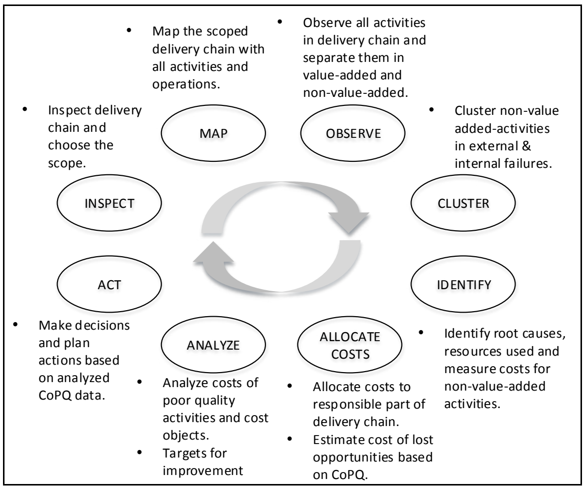

***Figure 29** Continuous process chart for measuring and reducing CoPQ in deliveries.*

Continuous process of improving quality in deliveries starts from inspecting and scoping desired delivery chain and leading to actions for improvements. Before actions the delivery chain has been mapped out and costs of poor quality has been observed and allocated to their root causes, providing holistic and detailed information of CoPQ in deliveries. This CoPQ can be then used for analyzing the delivery chain and different decisions and finally choose the best fitting and well targeted actions for improvement. After actions, affections should be evaluated, and if needed make an iterative improvement process again.

9.3 Academic contribution

In literature CoPQ was commonly expressed as a percentage of revenue (Crosby 1983; Feigenbaum 1991; Krishnan 2006; Williams et al. 1999; Harrington 1999; Juran & Godfrey 1998; Giakatis et al. 2001). Of course this tells the overall level of CoPQ, but for companies who want to improve their processes, this doesn't tell much. Moreover percentage of revenue seems to be very company and industry related, when it could be measured in many different ways and industries are varying a lot from each other. In case company CoPQ was 1,21% without and 3,22% with opportunity losses, which are both relatively low rates. However quality can't be evaluated only with this one number. For deeper and more detailed view CoPQ should be divided in internal and external failure costs with costs of lost opportunities. In this case study delivery chain was also divided further to responsible parts and failures were divided in poor quality activities. This made it possible to analyze and track poor quality costs to their root causes and that way create more comprehensive view of CoPQ in case company.

Because wide range of different frameworks for CoQ and CoPQ was introduced in literature, whole subject felt first confusing and messy. Literature didn't really provide ready-made background for this research. That's why the revised CoQ framework, illustrated in figure 30, was formed as a synthesis of previously introduced frameworks in literature.

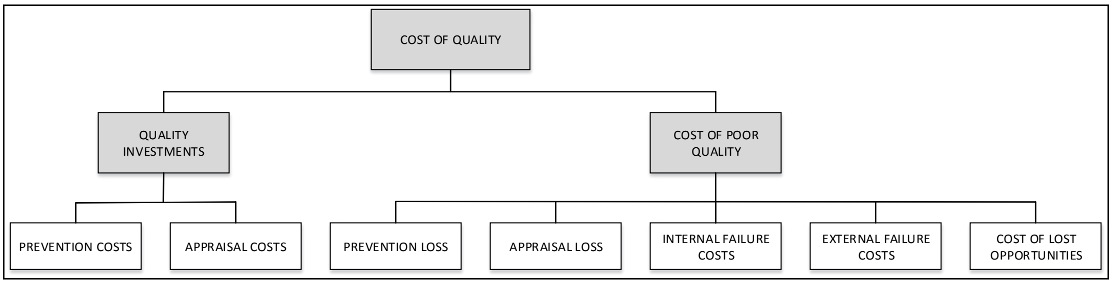

Figure 30 *Revised theoretical framework for CoQ.*

This revised CoQ framework is based on earlier frameworks introduced by Juran & Godfrey (1998), Harrington (1999), Sörqvist (1997), Giakatis (2001) and Thomasson & Wallin (2013). Revised framework divides CoQ in two parts: quality investments and CoPQ. Prevention and appraisal costs are quality investments made for achieving high quality, and that's why they should not include to CoPQ (Sörqvist 1997a). Like the name CoPQ is already describing, they are costs caused by poor quality. From this point of view CoPQ is caused because of investments to quality have been failed and poor quality occurs. Measuring and inspecting CoPQ organizations can identify the targets for quality improvement and follow-up the progress of on-going improvement projects. After targets for improvement are identified, organization can plan and take actions to improve quality through preventive and appraisal acts. When prevention and appraisal efforts have been used in best possible way, CoPQ should be reduced and quality improved. This explanation makes sense, that prevention and appraisal costs should not be understood as element of CoPQ, because they are totally different kinds of costs by nature.

9.4 Evaluation of the research

In this section, limitations of the research and its outcomes will be evaluated. Managers should be aware of how and which cases this information is valid, reliable and relevance to use, and when it’s not. It is important to recognize these limitations related to research and CoPQ model.

Validity is describing how well measure is illustrating the phenomenon or concept it should be, thus it is evaluating are we measuring right things. The purpose of this research was to investigate how poor quality occurs and how much it cost in deliveries of the case company, but more over to figure out how CoPQ should be measured. Because this case study shows one detailed way to measure CoPQ in deliveries, it gives valid information about practice how to measure CoPQ. This practice is valid to apply also in other context and circumstances. Because of time limitation of this research, the CoPQ model decided to cover only one mill and its deliveries to Central European markets within one year. Thus all CoPQ information is valid at least within the scope of research, but using this data for explaining situation in all deliveries in the case company should be highly questioned. Quality issues between mills, markets and delivery chains are highly differentiating from each other, and that’s why outcomes of this research should be used only for developing knowledge and creating specific CoPQ measures for those cases. Overall CoPQ models should always be customized to fit for specific use to ensure validity of measure.

Reliability in this research can be evaluated by observing data sources and how information was processed. Internal ERP databases were used for primary data source for all cost information. This was possible, since the case company doesn’t run any logistics operations but using external logistic service providers, and so costs were relatively simple to collect from logistic cost reports. Data from separate reports was carefully filtered to cover same time period and markets etc. limitations. Matching the market areas of sales and logistic cost reports was a little challenging because of different filtering factors, but finally sales and costs were synchronized and they are covering same deliveries. What it comes to labor and opportunity losses we have to understand possible inaccuracy they include. This is because information about lost labor or sales resources lost because of poor quality was collected with interviewing managers of those functions. Estimations are close to true and giving right magnitude, but they are still estimations.

Relevance of the research can be evaluated, how valuable information it provides for decision making process. The most relevant information of this research is the knowledge about, how poor quality costs should be measured and modelled in deliveries. This can be seen generally relevant always when creating models for measuring CoPQ. What it comes to relevance of CoPQ in deliveries of case company, it's good to remind once again about the scope of the research. Thus managers should understand the limitations of this research. However for decisions related to the delivery chain and quality improvement, this CoPQ model can be seen relevant source of information in most of the cases and can be used for knowledge development. The relevance of this research could have been maybe better if also prevention and appraisal costs would have been included. Then model would have been including all quality related costs, also quality investments.

9.5 Proposal for Future Work

This research provides a good starting point for continuous quality improvement process in the case company. Based on this research, the case company should next move on to determine and plan preventive and appraisal actions for improve quality in whole delivery chain. In case company this research can be also used as a reference, when applying this CoPQ measure in other parts and delivery chains in company.

For scientific research of quality management this work provides one real world case study example of CoPQ measurement in process industry environment. This thesis report gives quite detailed view, how CoPQ was measured, what we faced on our way and what we finally achieved. Obviously there's still need for this kind of real-world, practical case research information in study area of quality management. Especially CoPQ research from various industries and companies would be necessary.

The revised CoQ framework introduced in this thesis, offers a good and clear base for future research. Framework can be used as a guideline for categorizing quality costs and so achieve a clear structure for research. This study was only concentrating on CoPQ, and therefore research which would cover also quality investments, would be very interesting. By expanding the scope of research to cover whole CoQ, it would be possible to observe how well this CoPQ model actually support managerial work, and how it affect to quality in real action. As a conclusion this work shows, there is still much to do in study field of quality management and even more to improve quality in companies.

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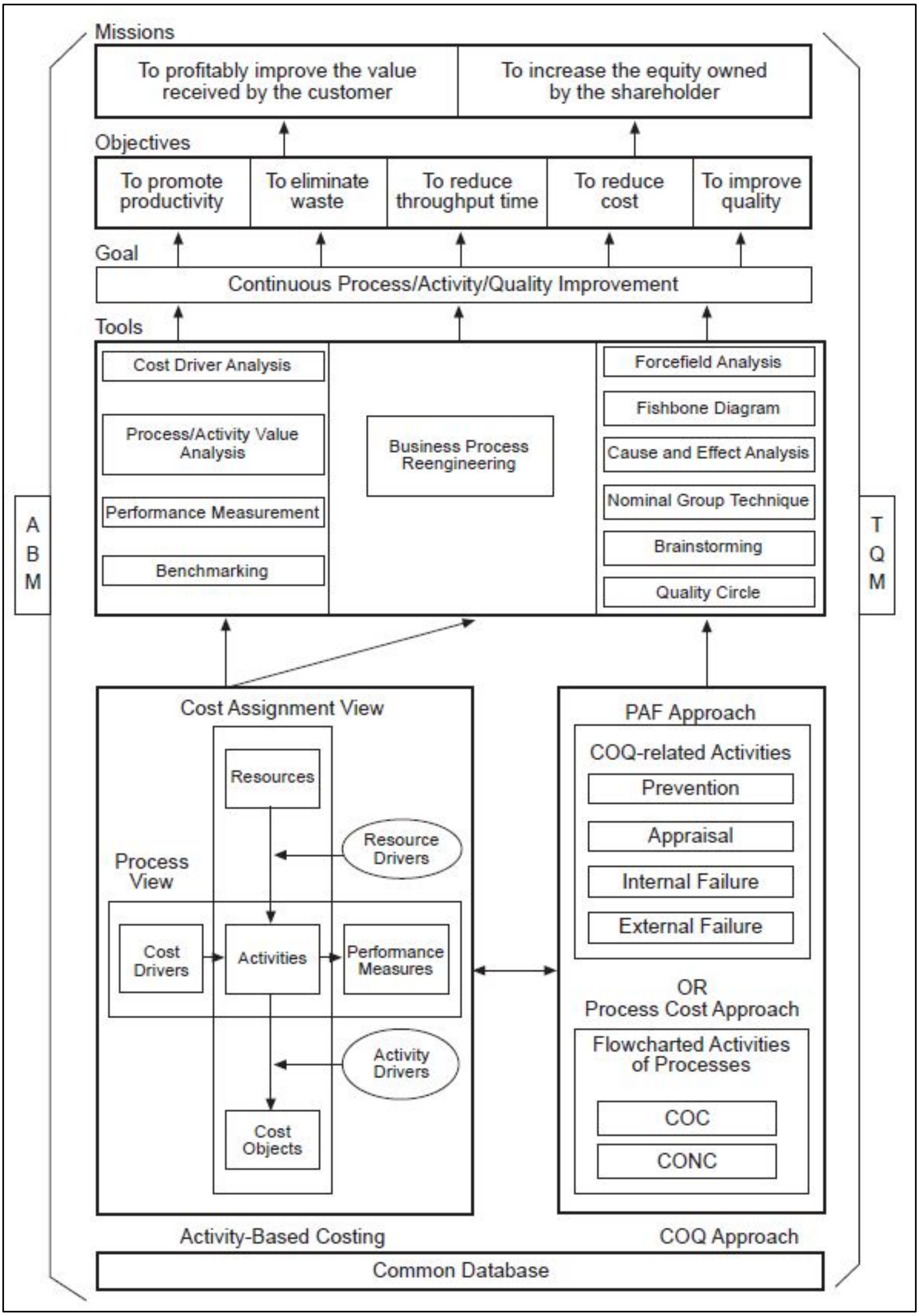
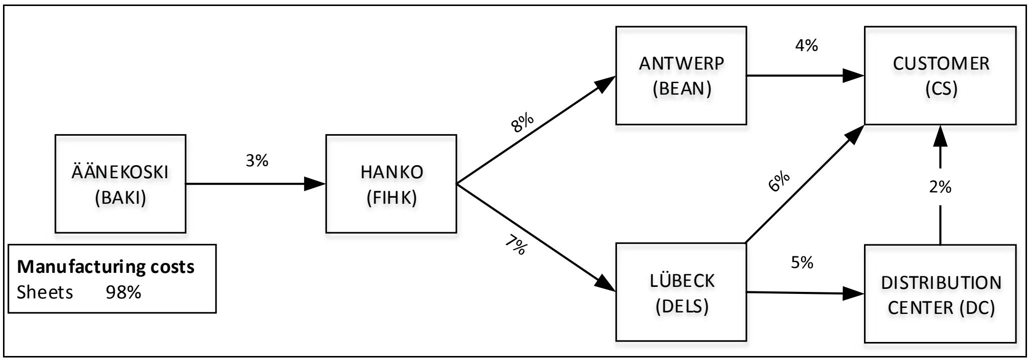
APPENDIX 1:INTEGRATED COQ-ABC FRAMEWORK BY TSAI (1998)

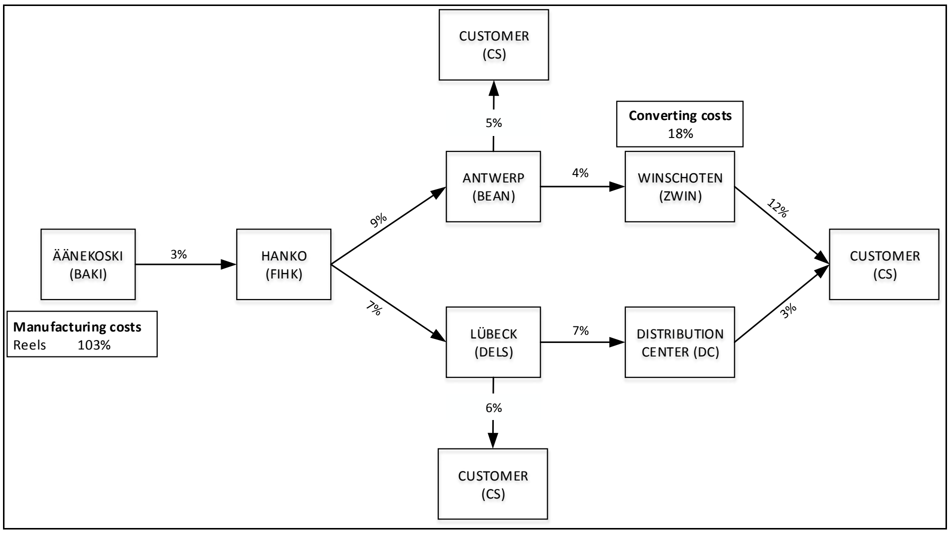


APPENDIX 2: COST STRUCTURES OF DELIVERIES FOR MTO AND MTS DELIVERED SHEET AND REEL PRODUCTS

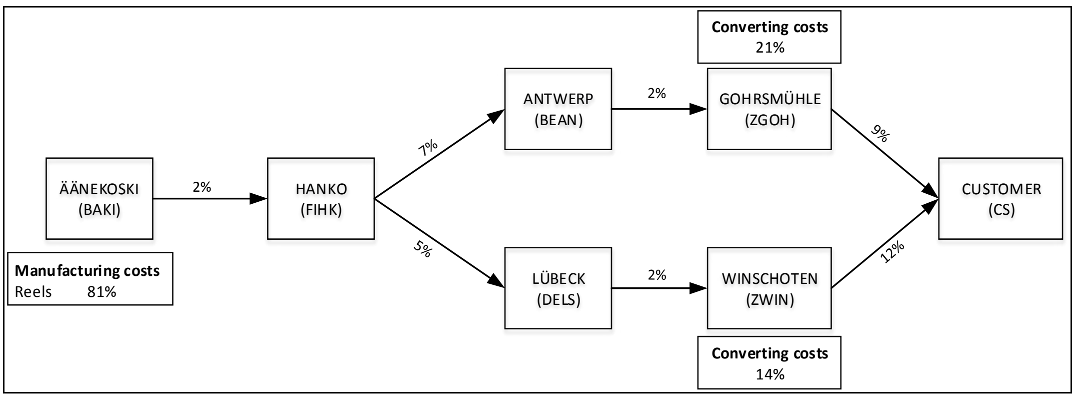
Make-to-order delivered sheet products:



Make-to-order delivered reel products:

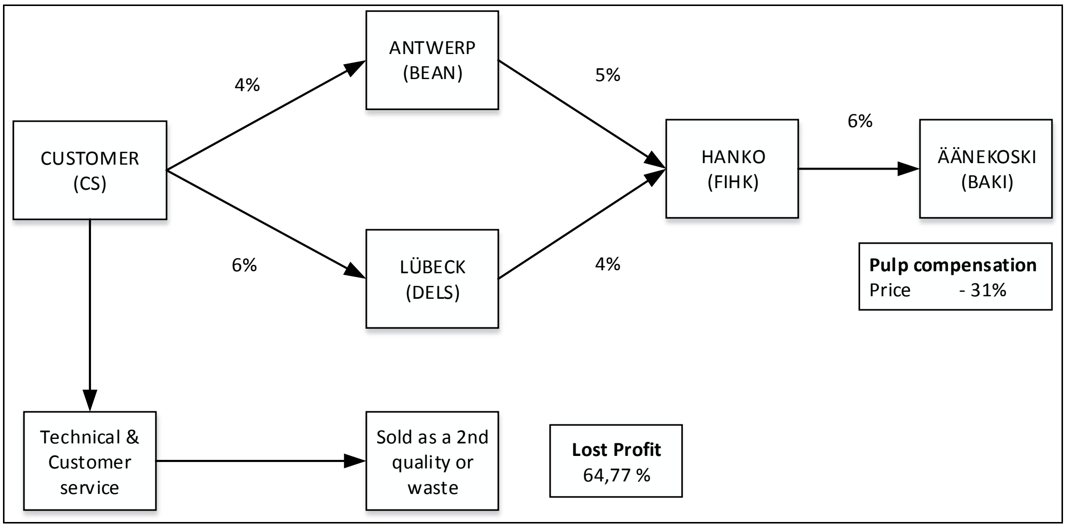


Make-to-stock deliveries:

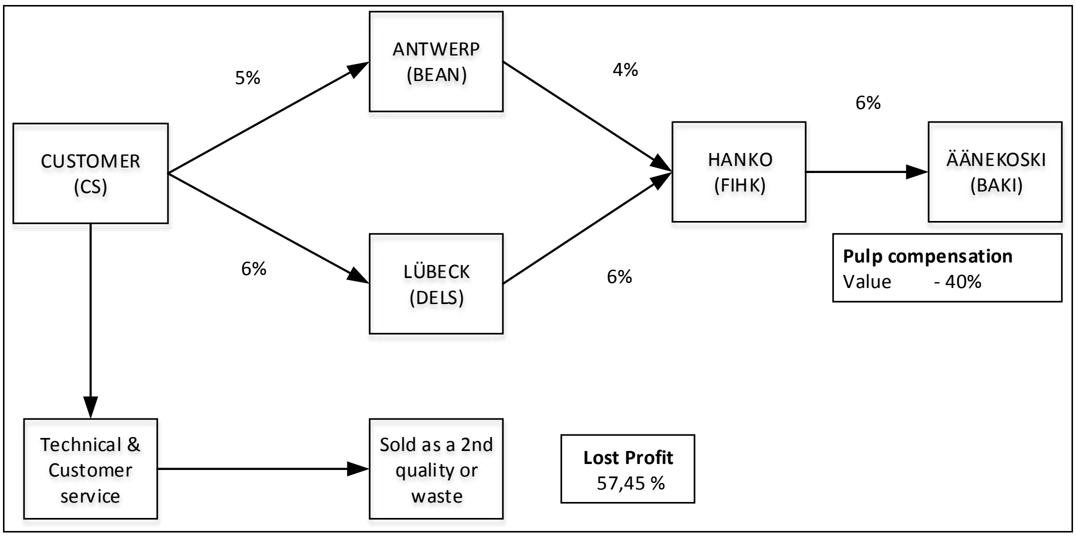


APPENDIX 3: COSTS STRUCTURES OF BACK TO MILL RETURNED SHEET AND REEL SCRAP

Back to mill returned sheet scrap:



Back to mill returned reel scrap:



APPENDIX 4: COMPLETE COPQ SUMMARY TABLE FOR CARTONBOARD DELIVERIES IN CASE COMPANY

Cost of Poor Quality																				
Poor Quality Activities		**Responsible department**																		
		Order handling		**Mill**		**Leg 1**		**Leg 2**		**Leg 3**		**External Converting**		**Technical & Customer Serv.**		**Sales**		**Total**		
		% of total CoPQ	**% of revenue**	**% of total CoPQ**	**% of revenue**	**% of total CoPQ**	**% of revenue**	**% of total CoPQ**	**% of revenue**	**% of total CoPQ**	**% of revenue**	**% of total CoPQ**	**% of revenue**	**% of total CoPQ**	**% of revenue**	**% of total CoPQ**	**% of revenue**	**% of total CoPQ**	**% of total CoPQ**	**% of revenue**
Internal	Internal Feedbacks	-	-	-	-	0,08 %	-	3,48 %	0,04 %	0,27 %	-	-	-	-	-	-	-	3,83 %	1,44 %	0,05 %
	Handling Faults	-	-	-	-	-	-	0,74 %	0,01 %	0,23 %	-	-	-	-	-	-	-	0,96 %	0,36 %	0,01 %
	Transportation Faults	-	-	-	-	0,84 %	0,01 %	-	-	0,06 %	-	0,02 %	-	-	-	-	-	0,91 %	0,34 %	0,01 %
	Warehousing Faults	-	-	-	-	-	-	0,08 %	-	0,01 %	-	-	-	-	-	-	-	0,09 %	0,03 %	0,00 %
	Non-standard logistic	-	-	-	-	0,08 %	-	1,47 %	0,02 %	0,13 %	-	0,01 %	-	-	-	-	-	1,69 %	0,64 %	0,02 %
	Faults in external converting	-	-	-	-	-	-	-	-	-	-	0,85 %	0,01 %	-	-	-	-	0,85 %	0,32 %	0,01 %
	Non-value-added labor activities	-	-	-	-	-	-	-	-	-	-	-	-	9,27 %	0,11 %	-	-	9,27 %	3,48 %	0,11 %
	Total	**-**	**-**	**-**	**-**	**0,99 %**	**0,01 %**	**5,77 %**	**0,07 %**	**0,70 %**	**0,01 %**	**0,87 %**	**0,01 %**	**9,27 %**	**0,11 %**	**-**	**-**	**17,61 %**	**6,62 %**	**0,21 %**
External	Product Feedbacks	-	-	15,77 %	0,19 %	-	-	-	-	-	-	-	-	-	-	-	-	15,77 %	5,92 %	0,19 %
	Service Feedbacks	0,55 %	0,01 %	0,81 %	0,01 %	0,73 %	0,01 %	0,73 %	0,01 %	0,73 %	0,01 %	-	-	-	-	-	-	3,53 %	1,33 %	0,04 %
	Transportation Feedbacks	-	-	-	-	-	-	-	-	0,20 %	-	-	-	-	-	-	-	0,20 %	0,07 %	0,00 %
	Lost profit (waste & 2nd quality)	-	-	1,78 %	0,02 %	1,78 %	0,02 %	1,78 %	0,02 %	1,78 %	0,02 %	-	-	-	-	-	-	7,11 %	2,67 %	0,09 %
	Returns back to mill	-	-	6,52 %	0,08 %	0,83 %	0,01 %	1,24 %	-	-	-	0,10 %	-	-	-	-	-	9,75 %	3,66 %	0,12 %
	Non-value-added labor activities	-	-	-	-	-	-	-	-	-	-	-	-	46,04 %	0,56 %	-	-	46,04 %	17,29 %	0,56 %
	Total	**0,55 %**	**0,01 %**	**24,87 %**	**0,30 %**	**3,33 %**	**0,04 %**	**3,74 %**	**0,05 %**	**3,76 %**	**0,05 %**	**0,10 %**	**-**	**46,04 %**	**0,56 %**	**-**	**-**	**82,39 %**	**30,94 %**	**1,00 %**
Total CoPQ (without opportunity loss)		**0,55 %**	**0,01 %**	**24,87 %**	**0,30 %**	**4,33 %**	**0,05 %**	**9,51 %**	**0,12 %**	**4,46 %**	**0,05 %**	**0,97 %**	**0,01 %**	**55,31 %**	**0,67 %**	**-**	**-**	**100,00 %**	**37,56 %**	**1,21 %**
Lost Opportunities	Lost reputation	-	-	-	-	-	-	-	-	-	-	-	-	-	-	62,44 %	2,01 %		62,44 %	2,01 %
	Total	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**62,44 %**	**2,01 %**		**62,44 %**	**2,01 %**
Total		**0,21 %**	**0,01 %**	**9,34 %**	**0,30 %**	**1,63 %**	**0,05 %**	**3,57 %**	**0,12 %**	**1,68 %**	**0,05 %**	**0,36 %**	**0,01 %**	**20,77 %**	**0,67 %**	**62,44 %**	**2,01 %**		**100,00 %**	**3,22 %**